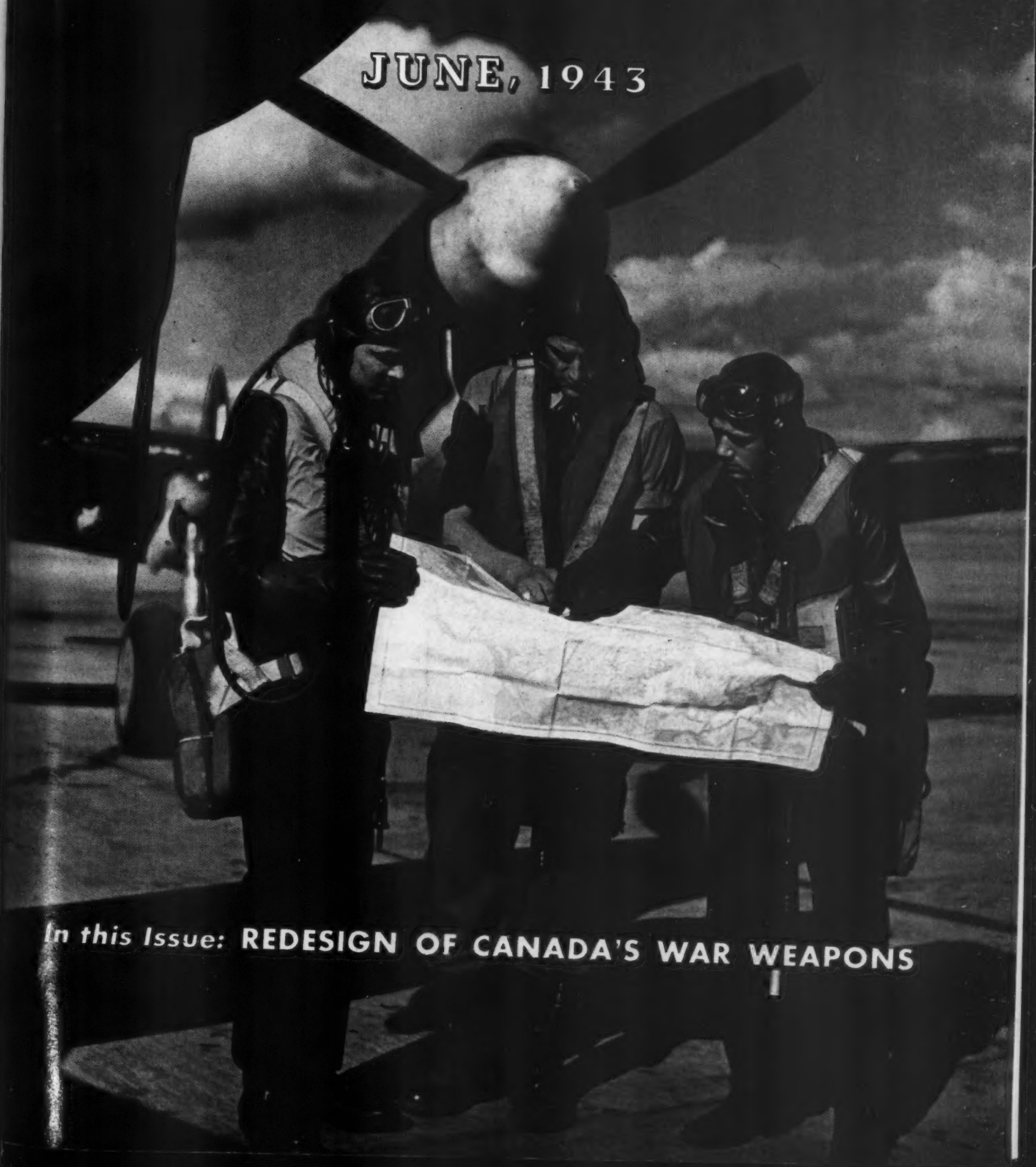
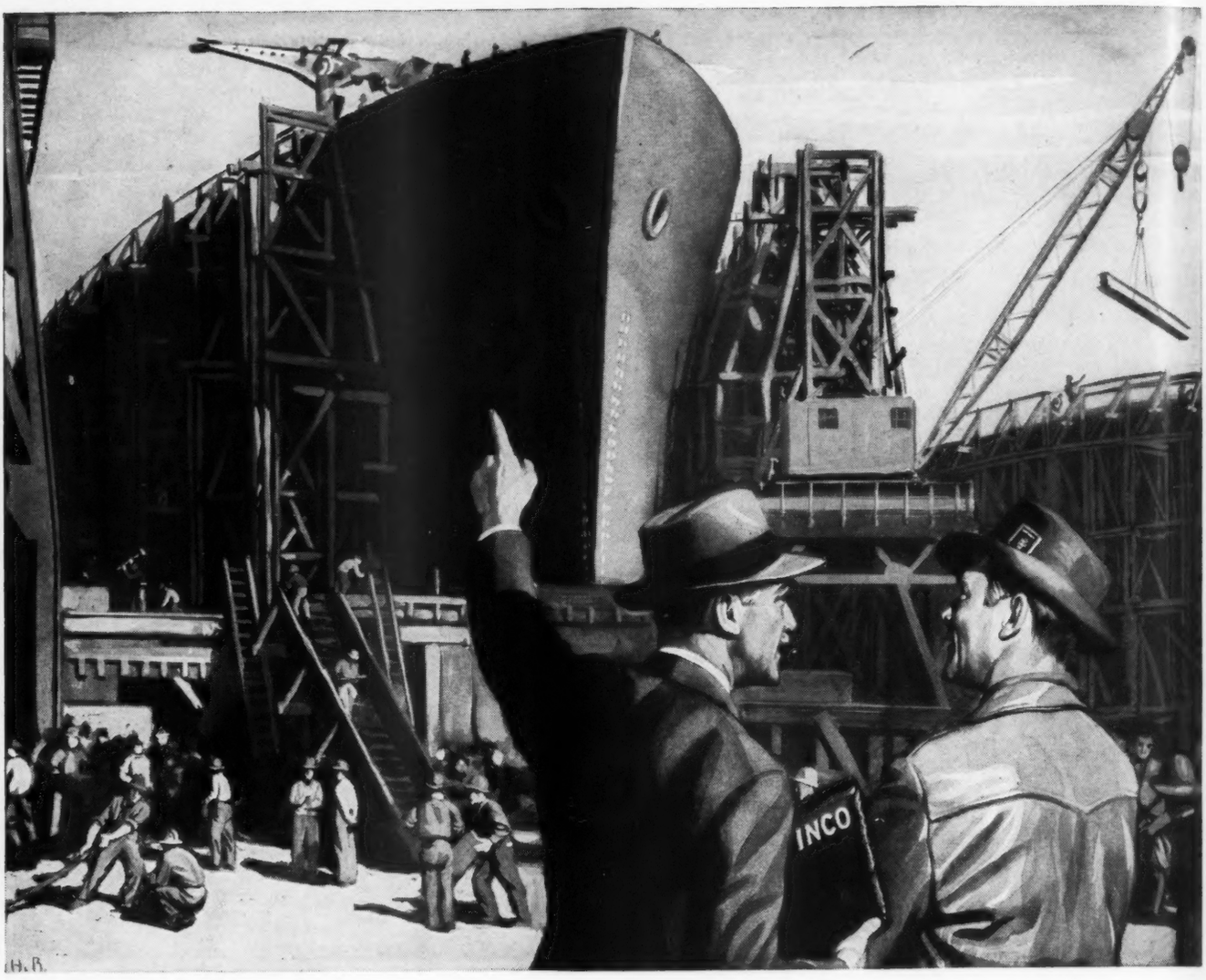
PRODUCT ENGINEERING

JUNE, 1943



In this Issue: REDESIGN OF CANADA'S WAR WEAPONS



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to KEEP 'EM SAILING!

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IN THIS ISSUE

This Month's Cover

Canadian pilots on Alaskan duty study a topographic map before taking-off on reconnaissance flight. Kodachrome courtesy Canadian Wartime Information Bureau.

Redesigns of Canadian Armament

One of the dramatic engineering feats of this war is the job that Canada has done in converting to war production. The fact is that Canada now makes one-fifth of the world's munitions. Her design engineers have done a great job in redesigning component parts to save critical materials, to ease up on overloaded fabricating facilities and to speed production of armament. The story in pictures and facts begins on page 327. Of particular interest is the "before and after" table which shows savings in materials, labor and costs made by redesigning small components.

Residual Stress and Fatigue

Mechanical causes of fatigue, as well as the shortcomings of present design and testing for the calculation and evaluation of residual stresses caused by prestressing material beyond its elastic limit, are discussed by J. O. Almen, General Motors Research, in a thought-provoking article "Effects of Residual Stress on the Fatigue of Metals," pages 348 to 352. Mr. Almen shows clearly when residual stresses are harmful, and

when beneficial. The article should stimulate engineers to do further research that will result in improved efficiency in the use of materials.

Organizing for Graphic Illustration

Despite the growing interest in production illustrations there has been little, if anything, said about organizing a staff to do this work. On page 366, John Gonzales, head of graphic illustrations, and R. R. Wiese, assistant executive engineer, for Fleetwings Division of Kaiser Cargo, Inc., present the first comprehensive discussion of the major considerations in establishing a graphic illustration department.

Selection of Metal Rectifiers

When low wattage a.c. is to be converted to d.c., rectifiers of three types are available: Copper sulphide, selenium and copper oxide. Before one can get the utmost value from metal rectifiers, it is important to know their characteristics, which in turn are influenced by time, temperature or operating conditions. I. R. Smith, Westinghouse Electric & Manufacturing Company, describes these characteristics on page 380.

Typical Mountings for Transparent Inclosures

Examples of typical flush mountings, pressurized-inclosure mountings, hinged joints, and acrylic and glass sheet connections are shown on pages 354 to 357. This is the concluding part of the article covering current practice in design of transparent aircraft inclosures, by A. C. Foster, of the Glenn L. Martin Company. The first part appeared in the May issue of PRODUCT ENGINEERING. Other aircraft companies which contributed examples are North American Aviation, Inc., Vega Aircraft Corporation. Republic Aviation Corporation and Fairchild Engine & Aircraft Corporation.

Designing With Magnesium

Bending strength calculations for magnesium alloys, in relation to designing for heavier metals, methods for overcoming its lower resistance to wear, and tolerances for interference fits for bushings are covered in the second part of the article on designing with magnesium, page 359. Resilience and toughness, and resistance to fatigue are also discussed, the latter with particular relation to stress concentration. Good design practice for magnesium alloy parts is also shown in a double-page spread on pages 374 and 375.

Die-Formed Sheet Steel

The Army's 6-foot diameter searchlight, designed before the war for relatively small-scale production with large aluminum castings, was redesigned for large-scale production in sheet steel, making use of idle automobile body presses and engineering experience in automobile body design. The result is a searchlight believed to be at least equally satisfactory, with interchangeable sub-assemblies, hundreds of pounds of aluminum saved on a single unit, and machining capacity released for other important uses. On page 333 the story of how the largest parts of the searchlight were designed is told.

Simplified Fluid Flow Calculations

To simplify fluid flow calculations, a nomographic chart was developed by The Glenn L. Martin Company for three specific types of oils, and for temperatures between 170 and −70 deg. F. An illustrative example is given on page 358 for the calculation of the unknown pressure drop.

Designing Die-Castings

With the April issue, there was published the first of a three-part article on "Factors to be Considered When Designing Die-Castings," by Herbert Chase. The concluding installment in this issue covers the design rules for threads, gears, inserts and combination dies. See page 376.

Characteristics of Motor Drives

Many types of motors, mechanical transmissions and combinations are available for driving machinery, to meet special load characteristics and speed conditions. This information is summarized in tabular form in the article, "Operating Characteristics of Electric Motor Drives," by L. H. Berkley on page 370. The engineer can select in addition to the customary a.c. and d.c. motor drives, some form of electronic control, conversion equipment with a.c. sources of power, or a form of variable-speed mechanical transmission.

Nozzles for Pressure Vessel

In the design of pressure vessels one of the most cumbersome and time-consuming details is to determine whether or not nozzle reinforcement is necessary. Recognizing the need for simplification of the procedure, Edward L. Maguire, a professional engineer, has prepared a table of factors for practical ranges of tank shell thicknesses and pipe sizes. With this table, given on pages 393 and 394, this determination can be made in accordance with A.S.M.E. rules with practically no computation.

PRODUCT ENGINEERING

WHAT'S COMING

Electronic Records of Plane Performance in Flight

Satisfactory analysis of plane performance can seldom be made on the basis of a few "critical" test measurements, as a complete investigation often requires simultaneous measurement of 50 or more factors. This is practically impossible to do manually. Faced with this problem Consolidated-Vultee Aircraft has designed electronic testing equipment which records 100 different instrument readings per second. The readings are radioed to a ground receiver. In a two-part article, PRODUCT ENGINEERING will give complete details of the equipment and its use and will describe calibration of instruments and conversion of signals to actual readings. This electronic testing method can be adapted to testing of automobiles, trucks, construction machinery and other powered units.

Deep-Drawn Aluminum Shapes

Deep-drawing with double-acting presses has many advantages in aircraft production because drawn shapes can often economically replace forged or welded assemblies. While considerable information is available on characteristics of ferrous and brass alloys for deep drawn parts, there is comparatively little tabulated data on aircraft aluminum alloys for deep drawing. In a comprehensive article, T. H. Hazlett of Lockheed will present design data on formability of various aluminum alloys and tempers, based on exhaustive tests.

PRODUCT ENGINEERING
JUNE 1943

Canadian Army Photo

Canadian Armament Redesigns Conserve Critical Materials and Increase Production

JAMES MONTAGNES

Changing from an agricultural economy to all-out war production meant many design and production headaches for Canada's armament industry. This article tells how engineers redesigned numerous component parts, thus saving time, labor, material, and releasing machine tools. Formed and welded construction, die-castings, malleable iron castings, and coining were all used.

OUTSTANDING among the production accomplishments of World War II is the job that Canada has been doing in turning out armament of all types from Bren guns to Mosquito and Lancaster bombers. Canada is today producing one-fifth of the world's munitions. One of the basic reasons for the success of this armament program is the redesign and conservation program being carried on by design engineers, who are constantly making a careful study of component parts in the light of available production facilities and materials. These studies have saved millions of dollars in part cost. But more important, these redesigns have meant tremendous increases in production and savings in precious time.

Advantage has been taken of formed and welded construction, die castings or malleable iron castings to replace hard-to-get forgings which require much machining. Where forgings were necessary for strength considerations, the forgings were carefully redesigned to make them easier to produce and to cut down machining time. Malleable iron castings—used extensively by Canadian engineers in prewar agricultural machinery—are being adapted to war equipment. Induction hardening has saved heat-treating time. Critical materials such as nickel steels and copper alloys have been replaced wherever possible.

On the six-pounder anti-tank gun mount, Fig. 1, top, original specifications called for an axle-tree assembly made of a large main forging weighing 190 lb., on which two 30 lb. forgings were shrunk and two 20 lb. castings were bolted. Considerable machining was required. The new design, shown in Fig. 1, bottom, consists of a built-up structure. Steel plate is formed up and welded to form the main section. To this section, two 5½ lb. steel forgings are bolted. Two 1⅛ lb. castings are welded on. It is estimated that the redesign will save 500,000 lb. of high-alloy steel a year. The manufacturer further estimates

that this redesign will release three engine lathes, one turret lathe, one drill press and a cylindrical grinder for other war work. Important, too, was the releasing of 115,000 man-hours for other vital work.

Several of the small parts on this gun carriage were also redesigned. The wheel hub, formerly two steel castings welded together, has been replaced by a malleable iron casting thus saving an estimated $86,600 a year and 260,000 lb. of steel. See Fig. 2. A nut from the trail support bracket and a cap were formerly machined 160,000 lb. of steel, formerly machined forgings. On the nut alone 160,000 lbs. of steel, formerly machined off, will be conserved. The cap redesign will save 84,000 lb. of steel. The pivot for the trail support bracket was originally machined from bar stock. The new design calls for a hollow forging which will release 106.-800 lb. of precious steel. The saddle

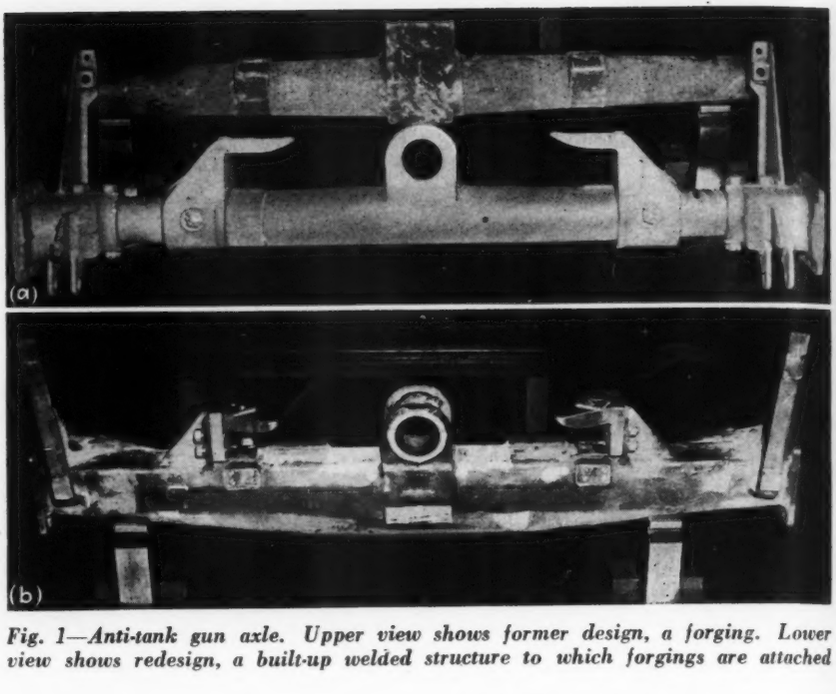


Fig. 1—Anti-tank gun axle. Upper view shows former design, a forging. Lower view shows redesign, a built-up welded structure to which forgings are attached

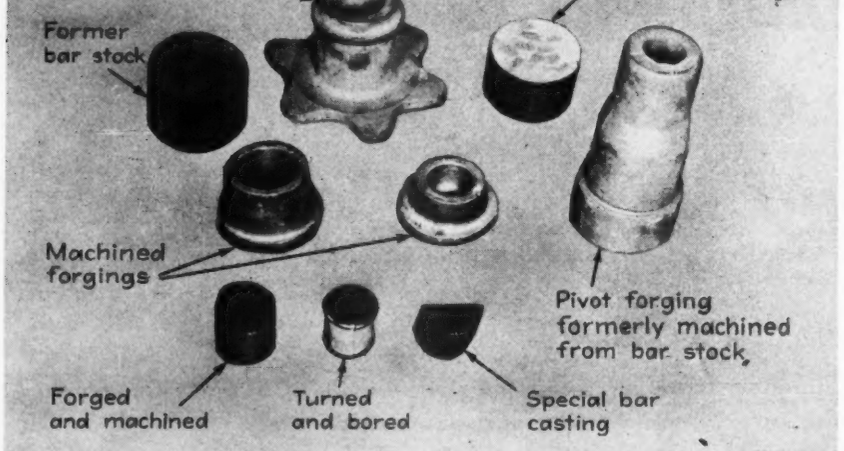


Fig. 2—Redesigned gun carriage parts utilize malleable castings and hollow forgings to replace parts formerly machined from bar stock

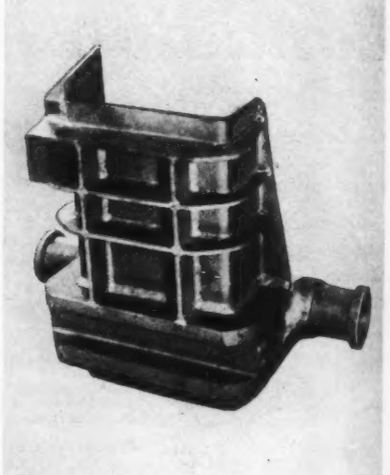


Fig. 3—Ribs are welded-on to this forging. They were formerly machined

capsquare liner was formerly specially cast bar stock machined, brazed, turned and bored. It has been replaced by a solid bushing made from cast bronze tubing. Sufficient strength and accuracy are thus obtained without extensive machining and drilling.

Savings have been effected also on other types of guns and gun carriages. The famous 25 pounder gun, which was so effective in North Africa, is made in Canada by Sorel Industries Ltd. Here the gun has undergone some redesign to save on strategic materials and to speed production.

Typical of the changes made were

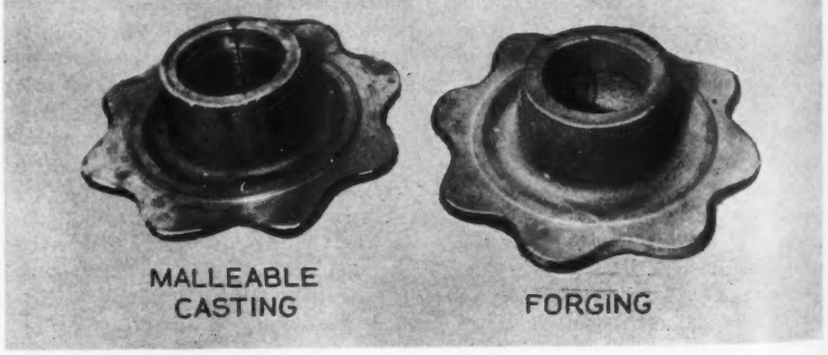


Fig. 4—55 lb. wheel hub, now cast of malleable iron to close dimensions

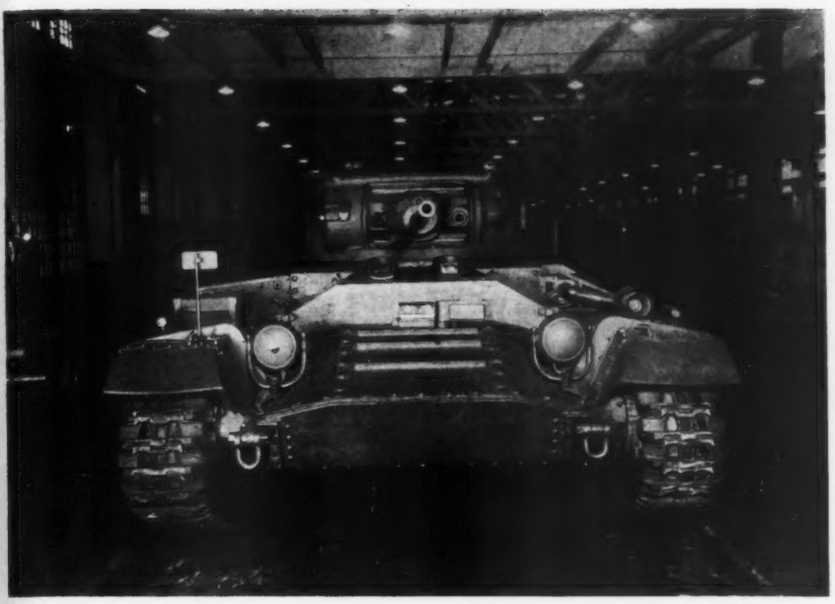


Fig. 5—Valentine Mark VII tank nose was formerly a built-up structure, riveted together. This assembly required 14 pieces of armor plate, 11 pieces of steel plate

the following: The trunnion band for the carriage of the gun was formerly an intricately ribbed shape machined from a steel forging. The slow machining operation required the use of four milling machines to form the spaces between the webs. This took too long for mass production requirements and it was decided to machine the main cradle portion including the two trunnions from the forging, then weld on steel plates to form the ribs, thus completing the trunnion assembly. See Fig. 3. This meant considerable savings in machining time. 120,000 lb. of steel are saved annually at capacity production and 150,000 man-hours of labor and machining are released. The cost saving was $650,000 a year.

The saddle for the carriage was formerly made of nickel steel plates, stamped, formed and riveted. Now mild steel plates are cut to size, stamped and welded, saving a ton of nickel a year, 150,000 hours of labor and approximately $840,000 in cost. The new material is easier to work. Drilling and riveting are reduced.

The 55 lb. wheel hub, formerly a steel drop forging machined all over, is now cast from malleable iron, cast closely to shape. See Fig. 4. The design requires less machining time because cutting is easier. It weighs but 31 lb. The change saves 740,000 lb. of steel a year at capacity production, 35,000 hours of labor, two lathes and $310,000. Roughly the various conservation measures on this gun alone at this one plant mean an annual cost saving of over $2,000,000. This saving includes such small items as colored glass for the siege lamp lenses. The engineers specified cellulose acetate for the colored glass lenses.

The nose of the Valentine Mark VII tank was originally made from 14 pieces of armor plate and 11 pieces of mild steel plate, one bullet proof drop forging and bullet proof rivets and bolts, the whole assembled after machining. This required a great deal of work. Machining specifications called for a perfect fit on all critical joints, many of which were at compound angles. The whole nose is now a one piece armor steel casting, machined. Better performance in the field resulted because of the improved contours. Savings in annual production represent 205,000 man-hours, the freeing of 21 machine tools and $75,600 in cost.

Similarly the turret was originally constructed of 3 pieces of armor steel cast, 2 pieces of armor steel formed plate, with machined fits and assembled with bullet proof bolts. A one piece machined armor steel casting replaced this assembly. Bolts are countersunk to obtain smoothness of contour.

In the manufacture of Bren automatic machine guns by John Inglis Co. Ltd., Toronto, one of the largest machine gun plants in the world, numerous changes were made in the design of component parts for conservation and production reasons. Typical are these:

The rear catch of the magazine was formerly built up with a welding rod and then machined to size and shape, requiring six operations. See Fig. 7. In the new stamped design, the catch contour is extruded to correct size by pressure, using only three operations. There was a material saving of 198,000 lb. of copper coated welding rod annually, $39,000 worth of oxygen and acetylene, a saving of 515,592 man-hours of labor, and the release of 10 milling machines and 24 welding positions.

The pin mounting for the Bren machine gun, Fig. 8, was formerly forged in one piece, then machined. Now the handle is stamped, the mounting produced in an automatic screw machine, and the two parts welded to-

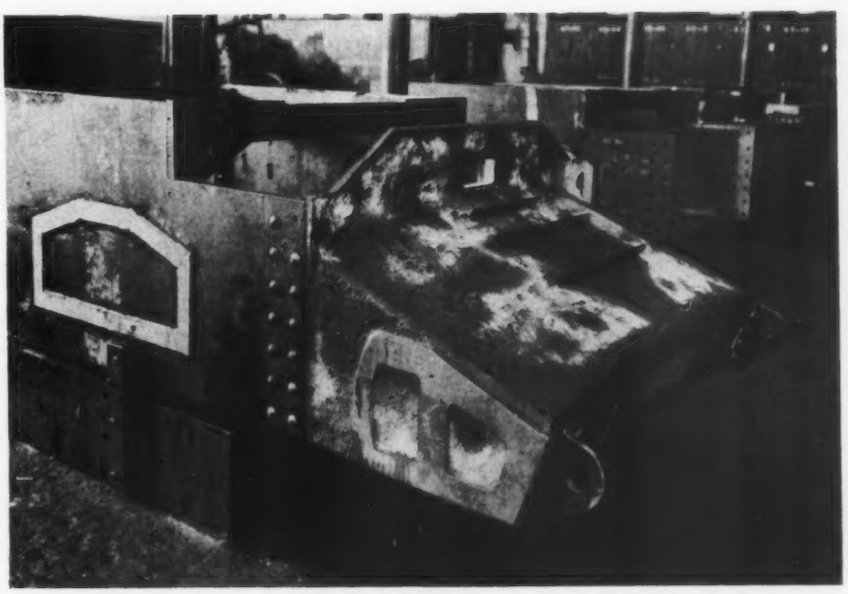


Fig. 6—Redesigned nose of Mark VII Valentine tank, is now a one-piece armor steel casting. Countersunk holes are provided where rivets are required

Typical Design Changes and Savings of Canadian Munitions Manufacturers

Part and End Product	Original Raw Material and Original Process	Material and Process Substituted	Estimated Annual Savings in Lb. of Original Material and Cost
Front axle, centre portion, 3.7 anti-aircraft mounting, Mk III.	Steel forging BSS 5005/402 with drilled lightening hole heat treated.	Square bar stock, BSS 5005/201 lugs welded on, heat-treatment omitted.	$98,700
Support bracket, 3.7 anti-aircraft mounting, Mk III	Bronze casting machined and bolted to carriage plate.	Steel block welded to carriage body.	56,200 lb. bronze, 77,000 lb. steel substituted. $56,400.
Front axle, 3.7 anti-aircraft carriage, Mk III.	Steel forging, machined all over.	Steel bar stock with lugs welded on.	389,680 lb. $159,134.
Breech piece Mr 127, 2 inch Bomb Thrower.	Forged solid from S.A.E. 1040 steel	Cored malleable iron casting.	340,000 lb. steel. 210,000 lb. malleable cast iron substituted. $62,000.
Hub F1 2353 for wheel hub for 25 pounder gun.	Steel drop forging, machined all all over, weight 55 lb.	Malleable cast iron, machined partially, weight 31 lb.	740,000 lb. steel on basis of peak production. $310,000.
Bracket F! 3072 for Trail for 25 pounder gun.	Made of steel forging. 1 piece of construction.	Made of 2 steel forgings welded together, eliminating most of the machining between flanges on top and bottom.	5,000 lb. steel on basis of peak production. $40,000.
Trunnion band for carriage for 25 pounder gun.	Steel forging machined all over.	Steel forging, partially machined, welded together with steel plates to make trunnion band assembly.	120,000 lb. on basis of peak production. $650,000.
Elevating face plate AN5254 for mounting Mk III Bofors 40M/M anti-aircraft gun. Original bronze rough casting OFE 518; original bronze finish casting OFE 519; new Mechanite rough casting OFE 520; new Mechanite finished casting OFE 521.	Bronze casting machined.	Mechanite casting machined.	37,800 lb. bronze. 37,800 lb. Mechanite substituted. $10,400.
Sight bracket plate AN3043, for sights-mark 1 Bofors 40 M/M anti-aircraft gun. Rough sand casting OFE 510, finished sandcasting OFE 512, finished oilite casting OFE 513.	BSS-32 Grade 1 steel machined.	Oilite pressure casting, unmachined.	9,450 lb. BSS-32 grade 1 steel. 4,725 lb. oilite pressed casting substituted. $4,933.60.
Ring-outer supporting bogie wheel for Universal Carrier Mark I. FM 3A rough malleable casting; FM 3 B finished malleable casting.	Bar stock turned in automatic lathe.	Malleable cast iron machined only on the essential surfaces.	440.000 lb. $186,000.
Track Dime Sprocket for Universal Carrier Mk I. FM5A—Orig. Plate Stock FM5B—Orig. Rough Ring FM5C—Orig. Finish Sprocket FM5D—Subst. Casting Cluster FM5E—Subst. Rough Casting FM5F—Subst. Finish Casting.	Original sprocket was rough flame cut from plate and part finish machined all over.	Sprocket is now cast, only machine operations are boring inside diameter and drilling holes.	8,860,000 lb. $1,720,000.
Support Arm, Part No. 18289–4, for 3.7 Anti-Aircraft Davit Assembly.	High strength manganese bronze castings.	Malleable iron castings. Revised pattern equipment to facilitate molding. Coined 4½ in. dia. and eliminated machining. Eliminated two ½ in. dowel holes.	36,400 lb. bronze. $11,200 in material.
Band Upper for Rifle No. 4, Mk I.	S.A.E. 1115 carbon steel, a hinged assembly of 2 parts machined from bar stock.	S.A.E. 1015 carbon steel strip stock die formed lugs brazed to formed strip finished by simple machining operations accomplished by design change.	279,600 lb. $144,000.
Bolt Locking, for Rifle No. 4, Mk I.	S.A.E. 1055 carbon steel machined from bar stock.	S.A.E. 1055 carbon steel now an assembly of 2 parts, the handle is blanked in a punch press, the stud is made from auto screw machine accomplished by design change.	61,500 lb. $111,500.
Lower Prism Holder Tank Periscope.	Aluminum machined.	Zinc alloy casting, machined.	33,000 lb. aluminum and 72,600 lb. zinc alloy, casting substituted. $55,060.
Upper Prism Holder, Tank Periscope	Aluminum casting machined.	Bakelite.	79,200 lb. aluminum alloy, 29,700 lb. bakelite substituted. $755,885.
Deflecting Prism Holder. Rangefinder Type 37 — 1 metre.	Brass machined.	Aluminum bronze.	1,142 lb. brass, 134 lb. aluminum bronze perm. mould cast substituted. $903.
Swivel Joint. Tank Periscope.	Gunmetal machined.	Zinc alloy casting machined.	118,800 lb. gunmetal. 52,800 lb. zinc alloy casting substituted. $158,928.

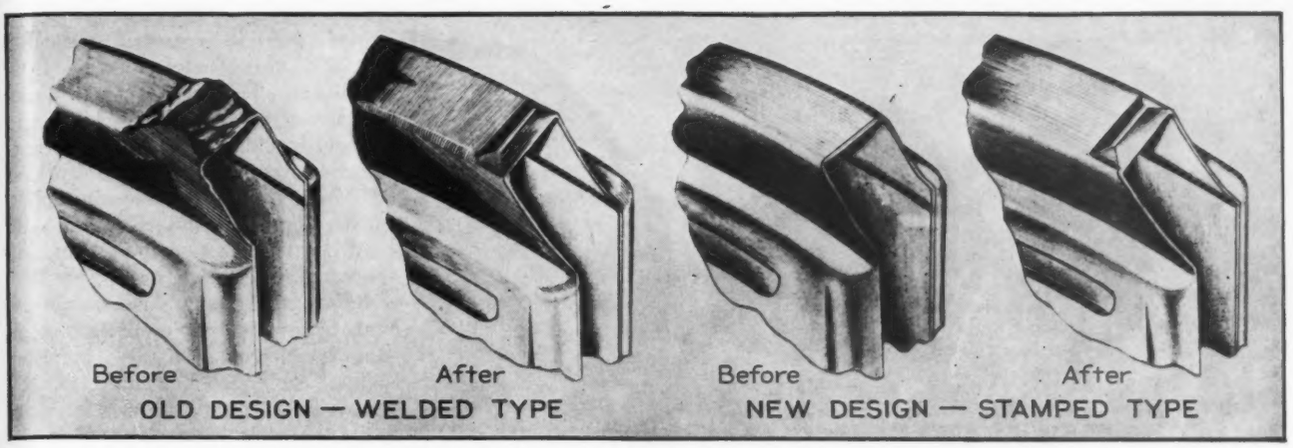


Fig. 7—Bren machine gun magazine catch, formerly machined to size, now stamped

gether. Annual production figures show that 103,200 lb. of forgings were eliminated on this small item, replaced by 32,000 lb. of bar and sheet stock, labor to the amount of 110,400 hours saved on production, and 17 machine tools were released.

The magazine platform for the gun, Fig. 9, formerly machined from bar stock, is now coin forged to close dimensions and machined, saving almost a million pounds of steel a year on 1942 production figures. Although the coined forging cost more, savings in labor absorbed the extra cost. Nevertheless many machine tools were released. The body of the Bren machine gun was formerly machined from a solid forging weighing 40 lb., 3 oz. The new design of the forging dies eliminated some machining operations. The new forging weighs 30 lb., 10 oz. After machining the body weighs 5 lb., 6 oz. The savings in annual production amount to 600 tons of special alloy steel a year.

The bipod for mounting the machine gun used to be made from seamless steel tubing imported from England. For hillside use a ratchet type extension leg joined to the bipod. This was eliminated in the redesign with approval of the army authorities. The bipod itself is now made from flat steel stock, rolled up in a five-step press operation, then welded together. See Fig. 10. The saving in labor amounts to 59,000 hours based on 1942 production.

Savings of nearly 400,000 lb. of steel on current production were made possible on 3.7 anti-aircraft guns by changing the front axle of the gun from a steel forging which had to be machined all over, to steel bar stock with lugs welded on. The center pivot of the gun was made from a solid steel block, machined to shape. Now it is made of steel pipe with a welded flange, saving 138,240 lb. of steel a year. Bolts were formerly locked to the mounting of the gun by a split pin through a milled slot. Now bolts are secured by standard lockwashers, saving two machine operations.

The pinion shaft on this gun mounting is another typical example of a labor and material saving redesign operation. Most of the shaft was machined down from 3¾ in. diameter steel rod to 2¾ in. diameter. Only a short section of 3¾ in. diameter was required. Now the shaft stock is 2¾ in. diameter. A washer of 3¾ in. diameter is added where the larger diameter short section is required, saving 232,000 lb. of steel, and about 1,460 man-hours.

Considerable savings were made possible by changing the oil tank on the 3.7 anti-aircraft gun mounting from a bronze casting to a welded fabricated steel structure. 86,500 lb. of bronze a year were replaced by 50,500 lb. of mild steel plate. The roller paths forming the anti-friction bearing on the platform and under the carriage were formerly made from steel hammer forgings. Now a steel bar is ring shaped and welded at the joint.

Scrap steel tubes replace flanged

Fig. 8—Pin mounting for Bren machine gun. The redesign consists of stamped handle welded to a screw machine part

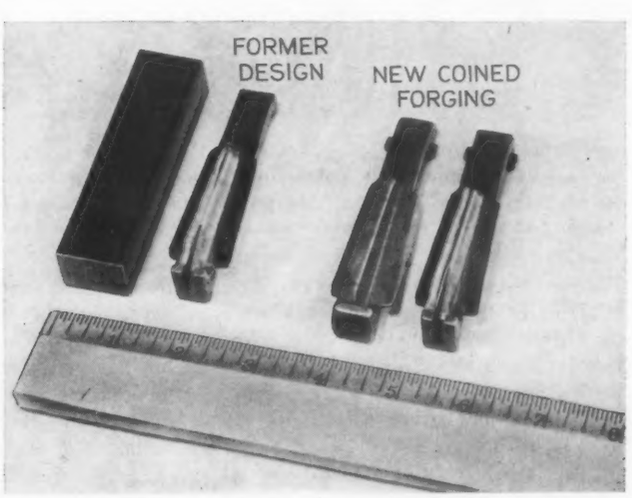


Fig. 9—Magazine platform for Bren machine gun is now cam forged to close dimensions and machined

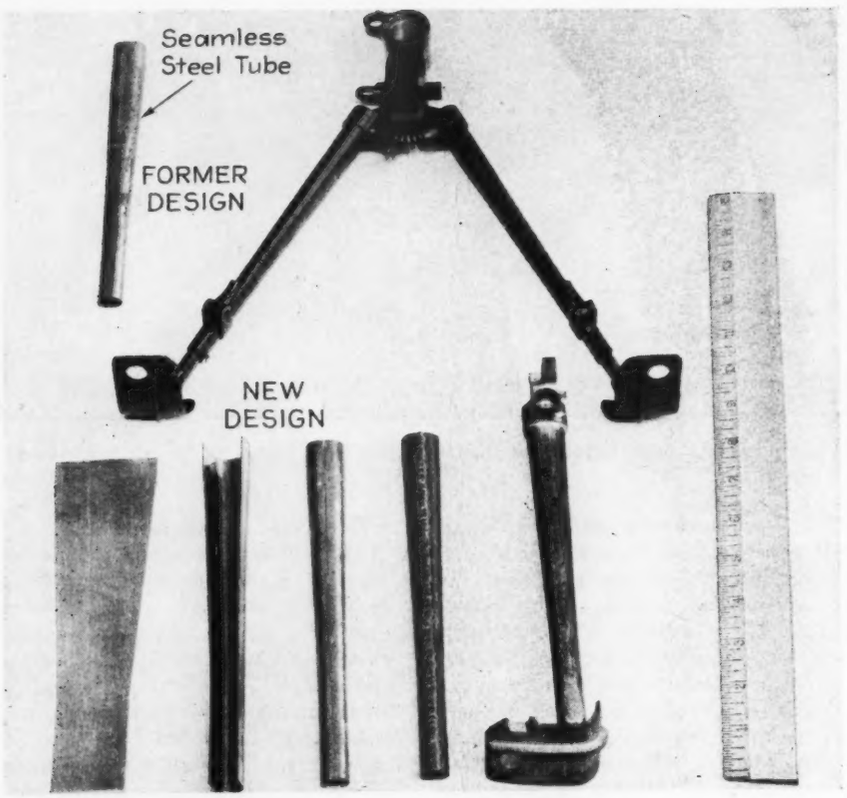


Fig. 10—Flat steel is rolled up and welded to form the Bren gun's new bipod

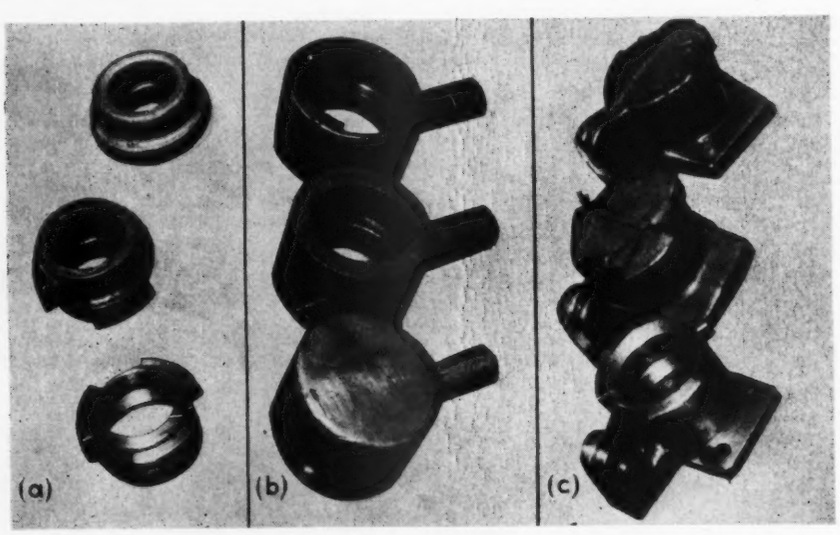


Fig. 11—(a) 2330 nickel steel forging replaced by malleable casting, shown in center; (b) another 2330 nickel steel forging replaced by malleable casting shown at top; (c) collar had integrally forged hinge. A separate forging is now welded to forged collar, simplifying machining and eliminating a milling operation

bronze rings in the gun carriage. Originally these flanged rings were machined and riveted in place. Now steel rings made from ends of scrap tubes are welded into place, saving machining and rivets, as well as 44,640 lb. of bronze.

The breech ring of 3.7 anti-aircraft gun was formerly made from a massive forging which came from Great Britain. Hamilton Munitions Ltd. and Dominion Foundries and Steel Ltd., developed an intricate steel casting which is later machined and tapped. Savings on current production by this method are estimated at 2,750,400 lb. of steel and 100,800 man-hours. Cost saving is $1,094,400.

In the Boys anti-tank rifle a number of savings have been effected. Typical is the recoil reducer, which was formerly a solid forging, cored and machined. Now it is cast in malleable iron with cored holes, requires little machining. This design saves annually almost 63,000 hours of labor and frees 11 machine tools. Labor savings per year in money are estimated at $31,473. The front magazine plate for the rifle was machined from a solid bar. It is now pressed from sheet, and the catch welded on.

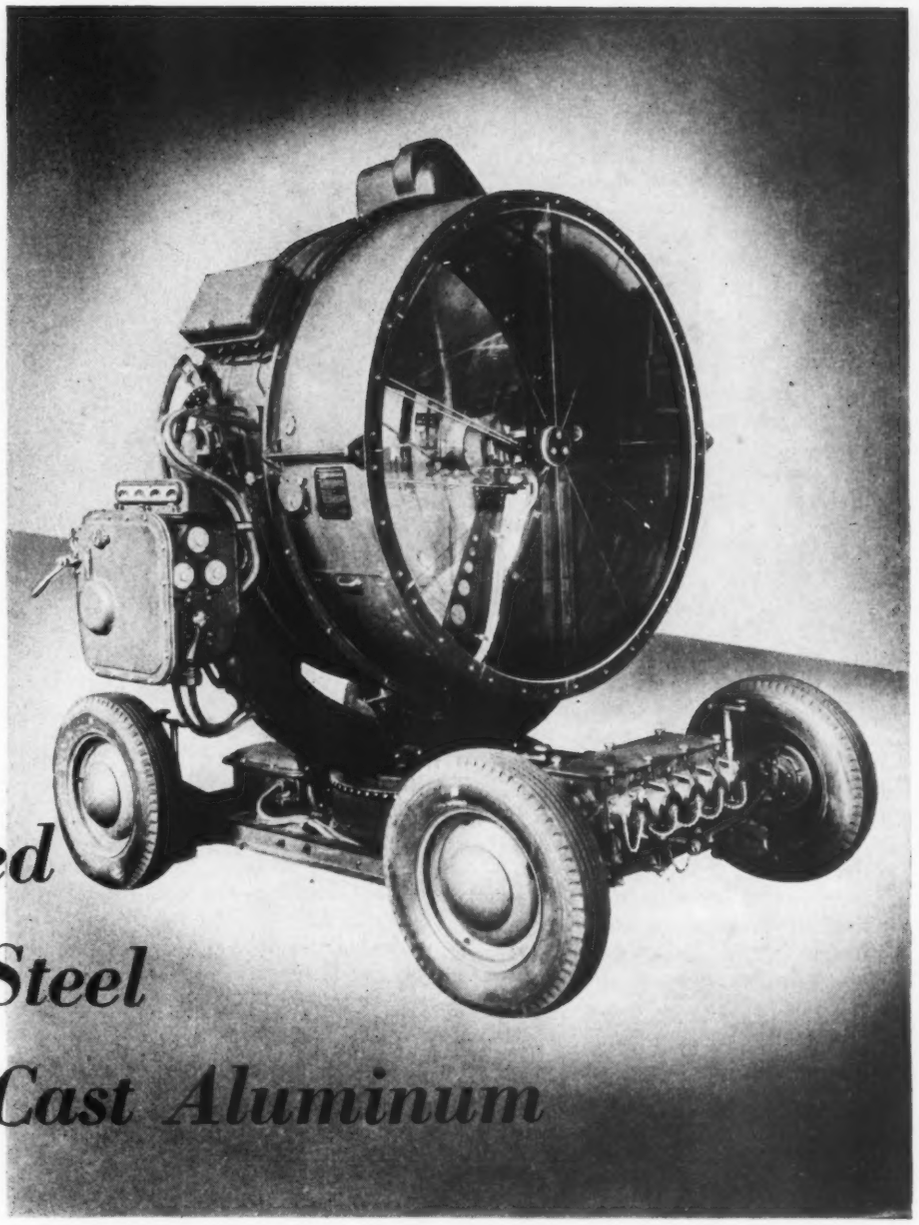
Before the war Canada made no tank periscopes, not even the optical glass which goes into these precision sights. An entire new industry, Research Enterprises Ltd., was set up to make the optical glass as well as the component parts for tank periscopes, range finders and numerous other secret pieces of precision apparatus. Canadian designers have revamped the design of the tank periscope to save materials, tools, labor and cost. They have used die-cast zinc and bakelite instead of expensive gunmetal, have substituted mirrors for prisms.

Another part of the tank periscope which has been redesigned is the swivel bracket, originally cast gunmetal, machined. Now it is die-cast from zinc, requires very little machining. Nearly 600 tons of gunmetal are saved annually by the new design.

Bomb throwers are another item on which savings have been made by substituting malleable castings or using extruded sections to relace a number of forgings. A nickel steel forging for a collar for the bomb thrower had to be machined out of the solid to make three lugs. Now a cored malleable iron casting, with the lugs almost finished to shape, saves 183,000 lb. of nickel steel a year. It requires 108,000 lb. of malleable iron, Fig. 11(a). The same process was carried out for a nut and the breech piece of the bomb thrower, Fig. 11(b), which saved considerable steel and machine tools. A collar with a hinge integrally forged with the collar was redesigned. The hinge and the collar are now separate forgings, welded together. Now turning of the outside of the body is carried out as a lathe operation instead of a milling operation. Also, machining is simplified.

As a further stimulus to redesign, the Department of Munitions and Supply sponsors a semi-annual manufacturers' meeting where before-and-after designs are exhibited, and where leading engineers discuss experiences in redesign. PRODUCT ENGINEERING will continue from time to time to publish details of outstanding Canadian equipment redesign. Manufacturers, Canadian Machinery and the Department of Munitions and Supply made data and photographs available.

Redesigning the cast aluminum drum and turntable of the Army's 6-ft. diameter searchlight for die-formed and welded sheet-steel construction, with interchangeability of most parts and all sub-assemblies, as described here, was an engineering problem equaling design of an automobile body. Saving of aluminum, production speed up, and release of machining capacity were important results of the redesign.



Die-Formed Sheet Steel Replaces Cast Aluminum

REDESIGN of considerable Army equipment and parts has resulted from the need for increased volume of production, conservation of strategic materials, and most advantageous use of available machinery. All of these advantages were obtained in the redesign of the Army's 60-in. dia. searchlight to use sheet steel instead of cast and sheet aluminum. In addition to the advantages gained by larger scale production, the new design was developed with insignificant increase in weight (less than 65 lb.), interchangeability of some parts and complete interchangeability of subassemblies between old and new design, and with no sacrifice in serviceability of the unit. In fact improvements in the product are argued by steel men and several production advantages are claimed.

Possibly the most important factor for designers to consider in the competitive positions of sheet steel versus cast aluminum is that die-forming is essentially a mass production method of fabrication and could not have competed in the small lot production before the war. Only when die costs can be spread thin can the selling price of a product be reduced below that of hand-made parts.

The redesign of the Army searchlight presented a problem to the engineering department of Murray Corporation of America that was the equivalent of designing a complete automobile body without benefit of a previous year's model. Something of the proportions of the job may be judged by the fact that 700 lb. of aluminum were saved in each searchlight built, as previously stated in November PRODUCT ENGINEERING, page 629. General Electric Company also had a leading part in directing the redesign. Considerably over 1,000 redesigned searchlights have already been produced.

The two main members of the searchlight are described and illustrated here along with brief discussions of the problems involved in their design. Because of the necessity for interchangeability of most parts and all subassemblies, the most important problems to be overcome were maintenance of all essential dimensions, prevention of distortion as the drum is rotated, and reduction of weight. Nearly equivalent weight was accom-

plished through the use of 13-gage S.A.E. 1020 steel sheet, which is $\frac{3}{32}$ in. thick, in place of $\frac{3}{8}$-in. aluminum. The overall design also had to be closely similar to the aluminum design in appearance. In some instances ease of fabrication was sacrificed for the sake of good appearance. Servicing of the lamp and interchangeability of subassemblies were also important factors in bringing about similarity in appearance. Thus the joint between the front and back sections of drum had to be in the same place to facilitate servicing.

An important factor in the design was available shop equipment. The largest presses in the Murray plant were called into operation in producing the drum. Even larger presses could have been used if available, and would have reduced the number of parts in the drum. In the present design the rear section of the drum consists of five major members, including the dished back, a band assembly made in three 120-deg. circular parts, and a 65-in. dia. rim flange to which the front section is bolted. This rim had formerly been machined on a boring mill.

Long experience in die pressing sheet steel has taught design engineers what may ordinarily be expected. However, some interesting departures from customary practice are the outcome of shop experimentation. In producing the dished back of the

FIG. 1

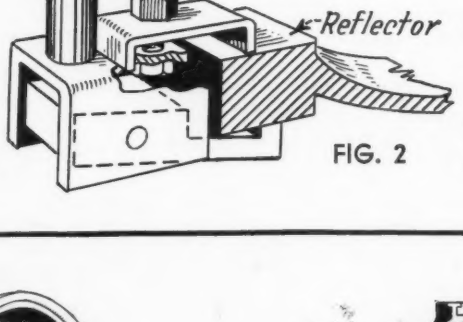


FIG. 2

Fig. 1—The pressed steel drum, shown bottom side up, consists of 5 major parts welded together: a dished back, a 3-part cylindrical section, and a ring flange to which the front section is bolted. Fig. 2—Reflector supports like this are spaced at 20-deg. intervals around the drum. Fig. 3—Cast aluminum and pressed steel drums show the possibilities of designing for interchangeability

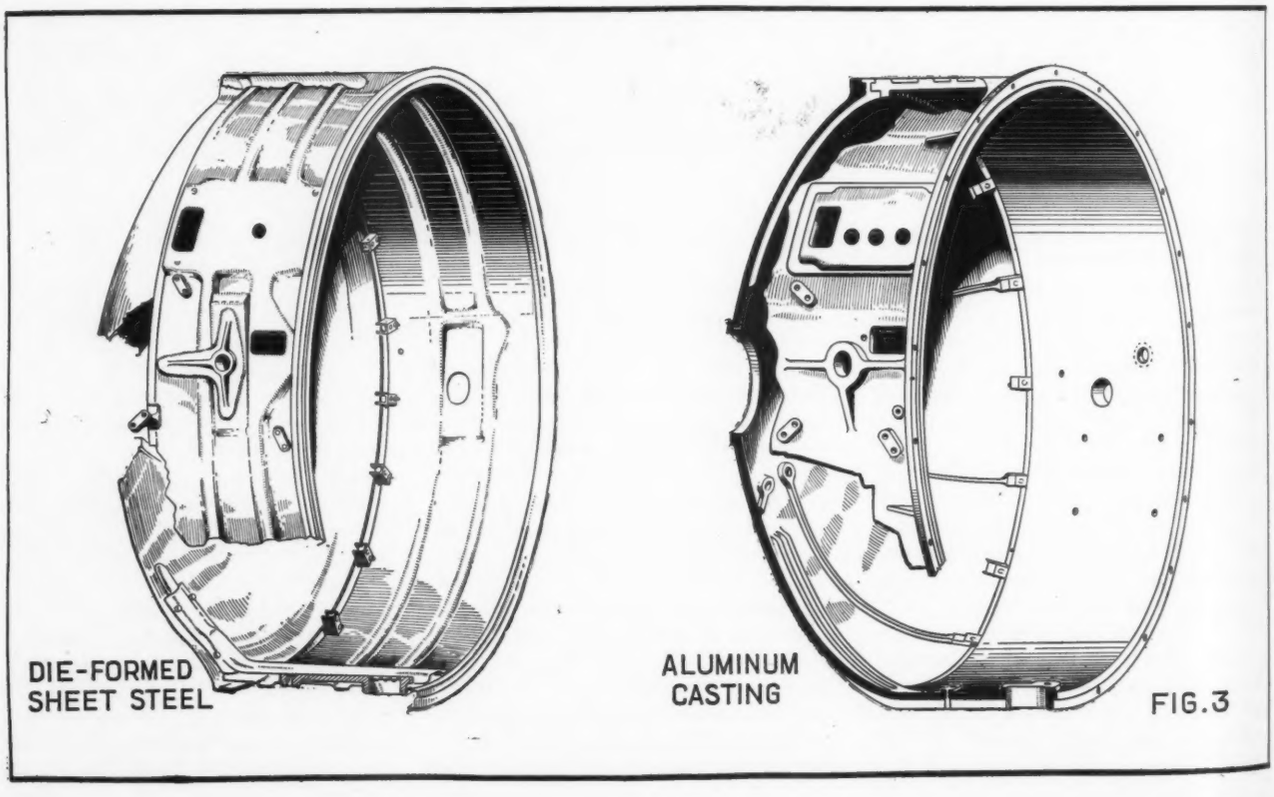


FIG.3

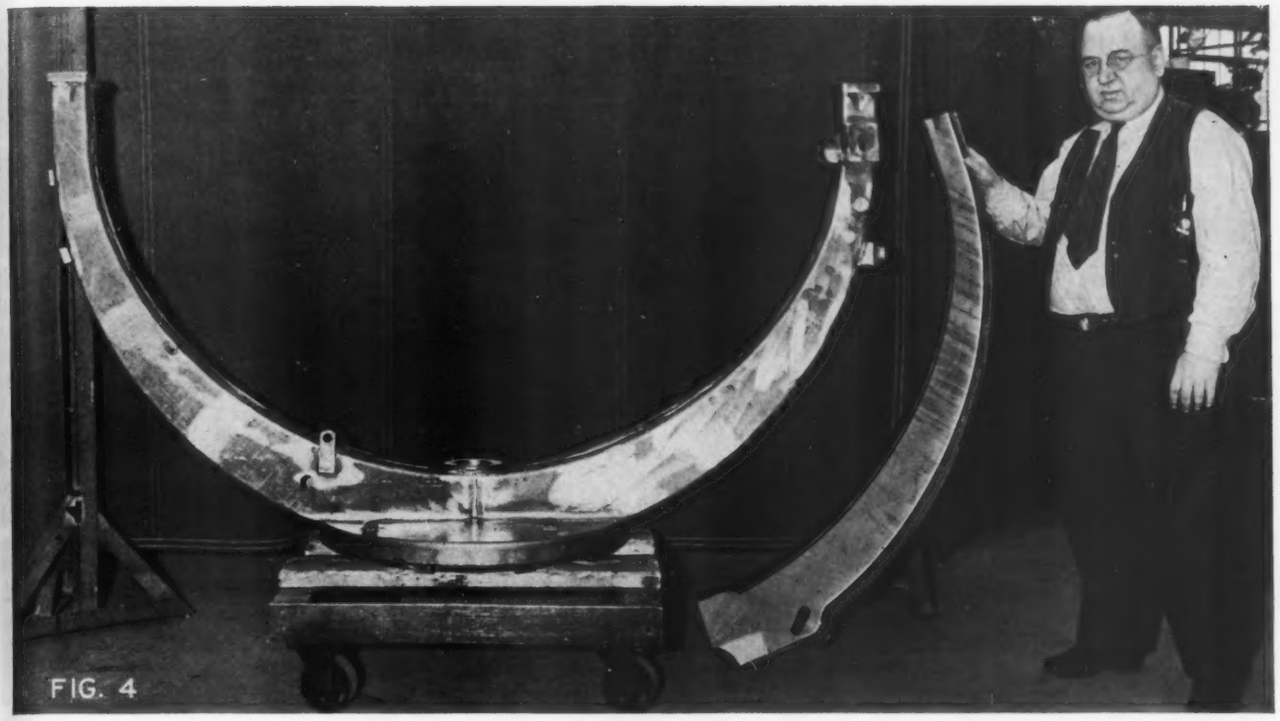


Fig. 4—The pressed steel turntable and half of an arm ready for welding

drum it was thought at first that in order to make the part in one press operation it would be necessary to design the part with radial ribs, as on the cast drum, to prevent formation of wrinkles in the metal, although such ribs were not necessary for stiffening. Preliminary trials with experimental dies proved that the wrinkles could be ironed out completely. The depth of dish at the center of the 5½-ft. back member is about 6 inches.

Machining Eliminated

The next problem was to find out how many machine operations could be eliminated. One of the large machined areas on the cast aluminum drum is a 12-in. dia. boss around a center opening of the dished back. Although the required flatness could not be made on the rough casting, it could be produced by the stamping operation. Other flat areas on the outside of the cylindrical portion of the drum where control boxes are mounted were also made sufficiently flat by stamping operations.

A good sized boss was put on the bottom of the cast aluminum drum on which to support the lamp. This boss was machined on a boring mill. This and other boring mill operations on the aluminum drum would have tied up 10 boring mills at the present rate of production of searchlights. Elimination of this and other machine operations was one of the principal advantages obtained in redesign. The supporting column was bolted to this machined surface on the aluminum drum. To avoid the necessity for extreme accuracy of mounting in the pressed steel drum, provision is made for adjustment of the column, which now is attached by movable bolts to a flat steel forging welded to the outer shell. In Figs. 1 and 3 the reinforcement of the bottom of the drum, on which the supporting column and forged base rests, is shown.

The small machined bosses that supported the edges of the reflector have been replaced by small adjusting fixtures, which are welded to the inside of the back of the drum at 20-deg. intervals. These are also visible in Fig. 1 and 2 and shows their operation.

The trunnion bearings were formerly a part of the cast aluminum drum. Since this part had to be almost solid metal for sufficient strength, and is simple in design, a steel forging was decided upon. The only machining required is the bored hole for the shaft trunnion.

Rigidity in the cylindrical members of the drum is provided by two formed circumferential stiffening ribs. These formed ribs are shown in Fig. 1. The section held by the welder has flat surfaces into which these ribs merge. The upper flat area is the mounting surface for the lamp mechanism box. The lower round opening is for a trunnion shaft. The trunnion bearing is welded to the flat surface around this hole and one leg is fitted around one of the reinforcing ribs.

A number of other minor parts are welded to the drum. These include reinforcing plates, air ducts for cooling, pads, and stainless steel weld-on nuts and bolts.

Turntable Design

The turntable supporting the searchlight was also an aluminum casting originally. This is now formed from ⅛-in. sheet steel. Stress computations were necessary before starting the redesign of this part. Since appearance was a big factor in the design, welding was kept flush as much as possible.

The required strength was produced by use of box sections with four internal ribs in each arm. These box sections are tapered both ways as well as being curved. A few hand openings were specified for welding. Each arm consists of two halves butt-welded together. It would have been simpler to have put on outstanding flanges for arc welding, but appearance would have suffered.

There are various reasons for making the arms separately, such as shop equipment, economy of production, and material. Although the two arms were not identical on the cast aluminum turntable it was found that no harm was done in providing for an extra bump, which was necessary for

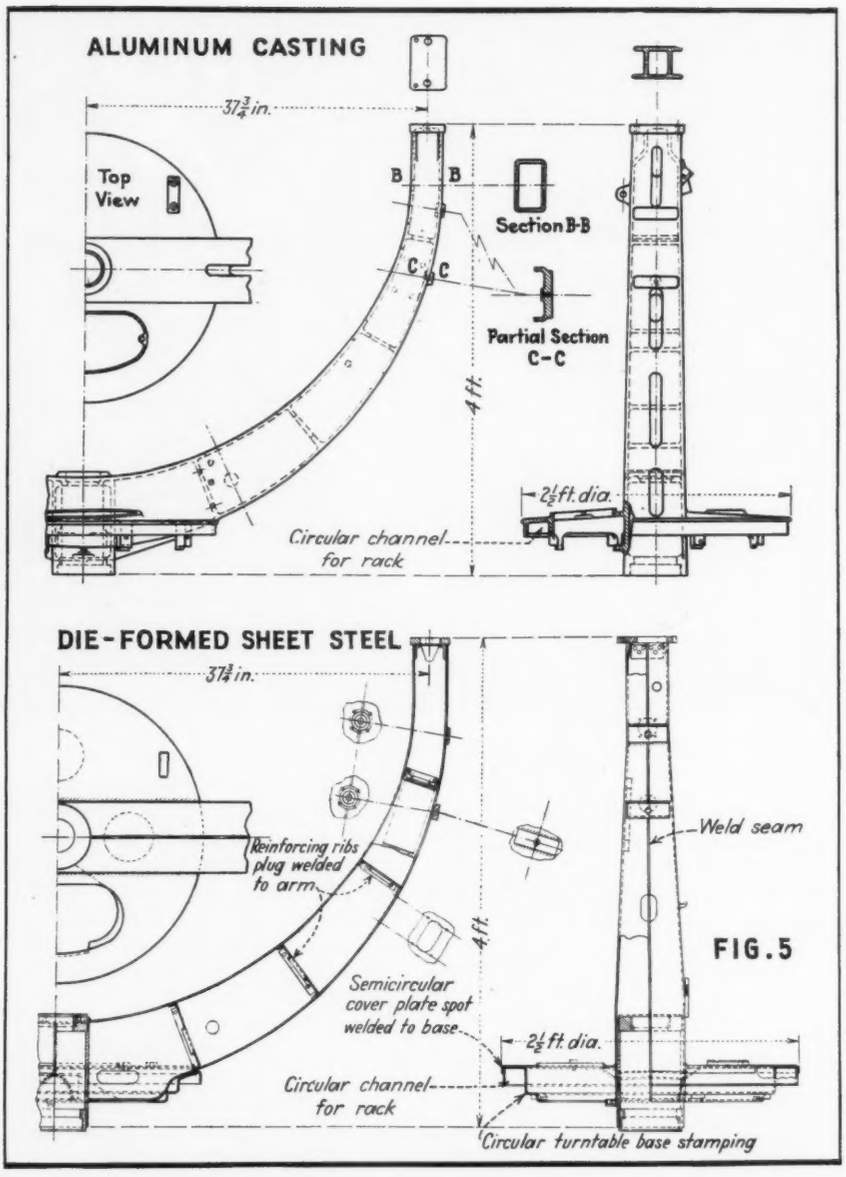


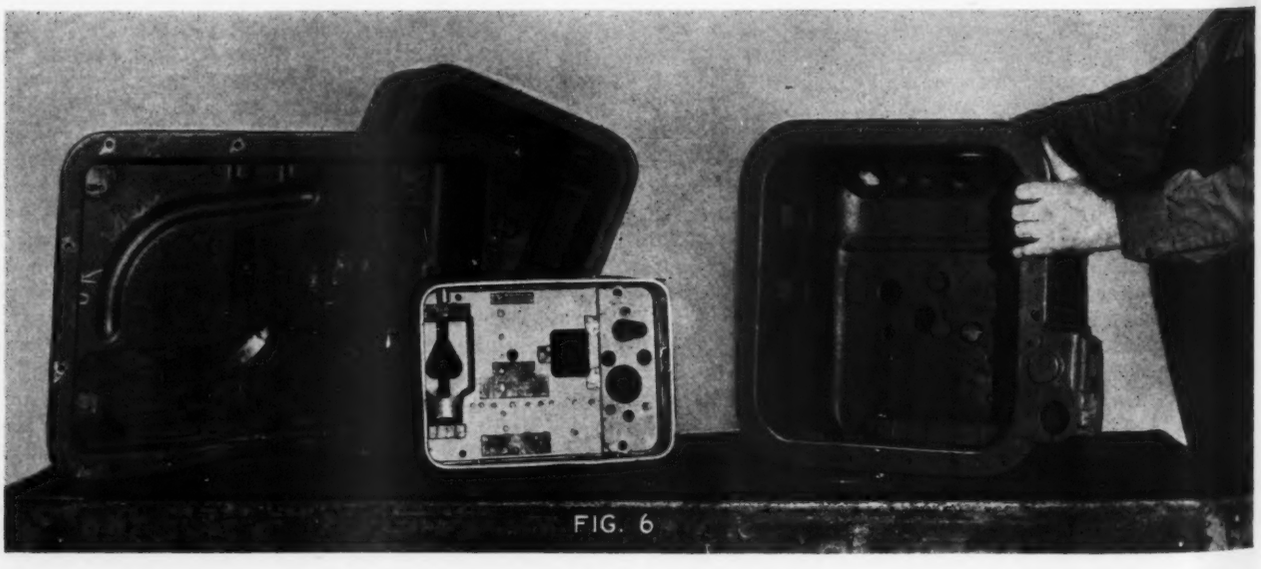
Fig. 5—Close similarity between the two designs of the searchlight turntable is evident. Fig. 6—Control boxes were also redesigned in steel

clearance on one arm, on both arms in order to save die costs. Fig. 4 shows both the assembled arms and half of one arm as it comes off the press. The V-shaped bump is at the top end of the arm.

The position of the ribs was not changed. These ribs are made with flanges for welding and are spot welded to one side of the arm before joining the two halves. The other half of the arm has holes at the points of welding so that welding can be done from the outside. The bosses on the arms had to be rigid and so were made of solid steel.

The round center section is made in two parts, which are spot welded together to form a boxed-in ring-shaped channel and a rigid supporting member. Blocks are welded at 45-deg. intervals in the channel as supports for the gear ring by which the azimuth position of the searchlight is controlled. Tubing is welded into the center to serve as a mounting for two ball bearings for the vertical shaft. The comparative drawings in Fig. 5 illustrate most of the features of the design, including the means of designing for stiffness in the arms and turntable base.

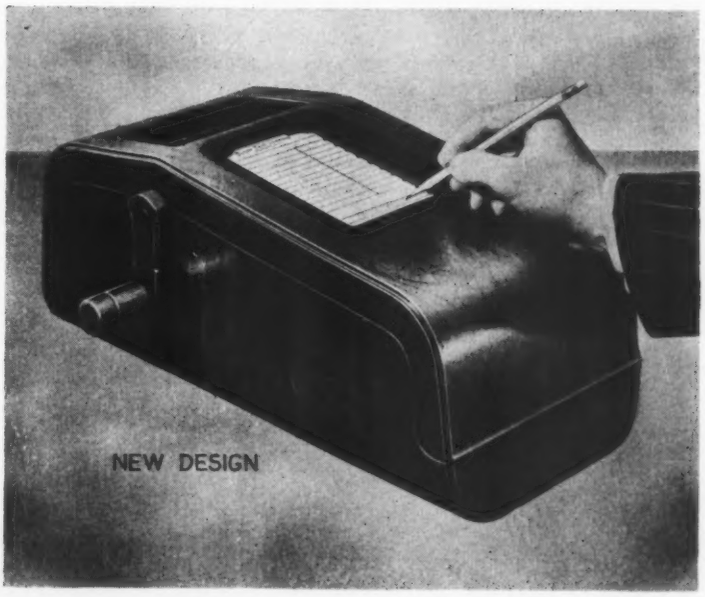
Control boxes were also redesigned in steel, using stamped sheet steel wherever possible, and combinations of stampings with castings. Considering the number of welded pads on these boxes it is doubtful whether these designs could compete with plentiful aluminum but they play an important part in saving for more important uses the 700 lb. of aluminum on each searchlight. At the left in Fig. 6 is the azimuth control box, in the center the lamp mechanism box, and the workman is holding the elevation control box.

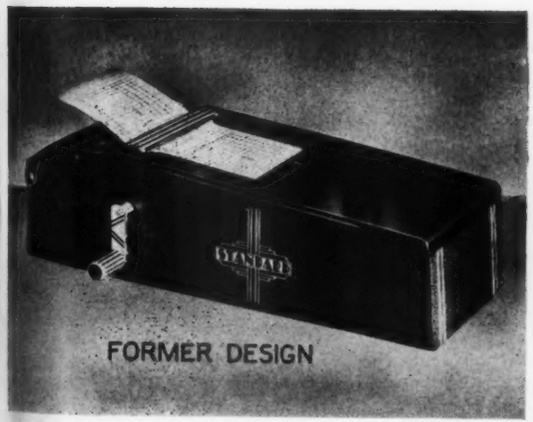


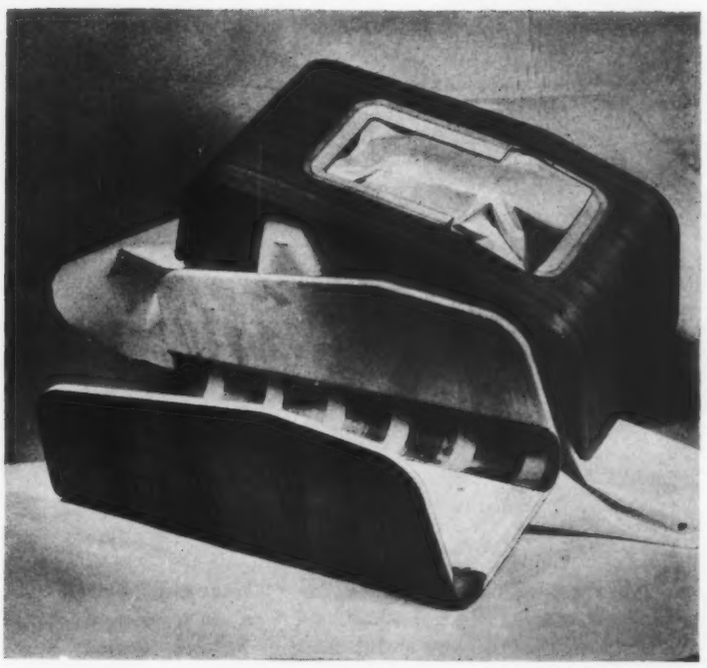
WARTIME DESIGNS

PLYWOOD AND HARDWOODS REPLACE CRITICAL METALS IN NEW BUSINESS MACHINE

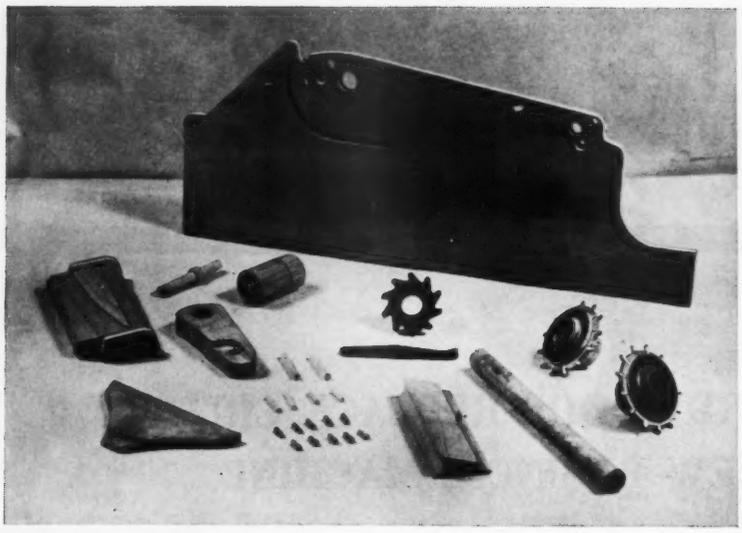
Housing and all working parts are of wooden construction in the new KFW model autographic registers designed by Standard Register Company. Former models were of steel and aluminum, although a recent redesign utilized molded plastics to a considerable extent (see PRODUCT ENGINEERING, April 1942, pages 226-227). Plastics, glass, ceramics, and impregnated paper were considered before the final wood design was agreed upon. Weight has been reduced from 17 to 8 lbs. without loss of efficiency.

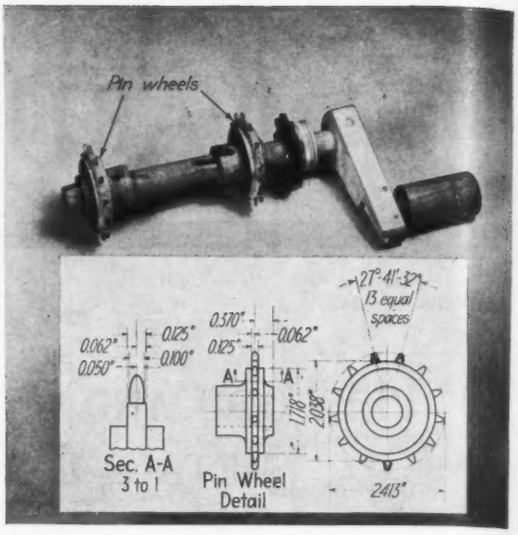






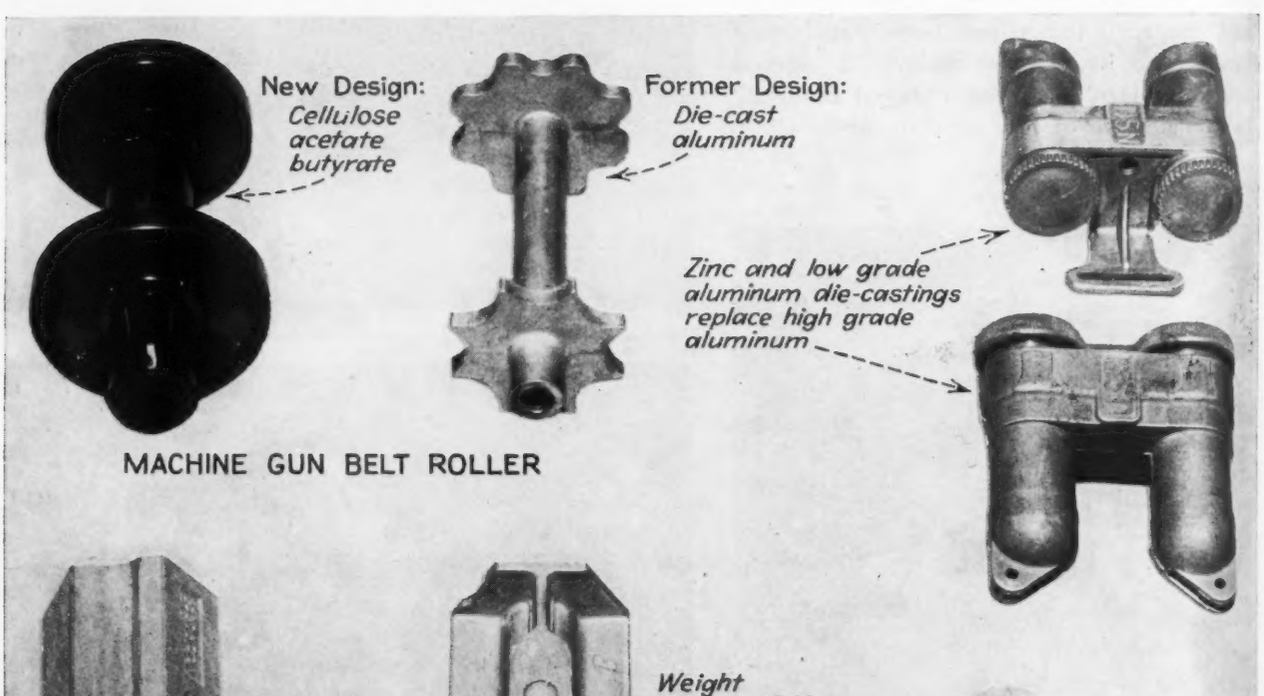
Cabinet and larger parts, right, are plywood construction. utilizing walnut, gumwood and basswood bonded with casein adhesive. 300 hours testing in 100 percent saturated atmosphere showed no deterioration in material or bond. Since writing table must withstand impact, tests were carried out on steel, glass and other materials before Masonite of die stock quality was selected. Forest Products Laboratory cooperated in the development. Certain working parts are machined from Masonite; others from hardwood. Tolerances are ±0.005 in.





Wooden working parts in new design, and detail of pinwheel and handle. Wood clock mechanisms were usually made of fruit tree wood, in particular apple tree because grain ran at random angles through piece, giving almost uniform strength in any direction. In this design, suitable strength was obtained by use of Masonite die stock for parts such as ratchets and pawls. All other working parts with exception of springs, pivots and pins, are machined white maple and brick. Moisture content of wood used does not exceed 5-7 percent.

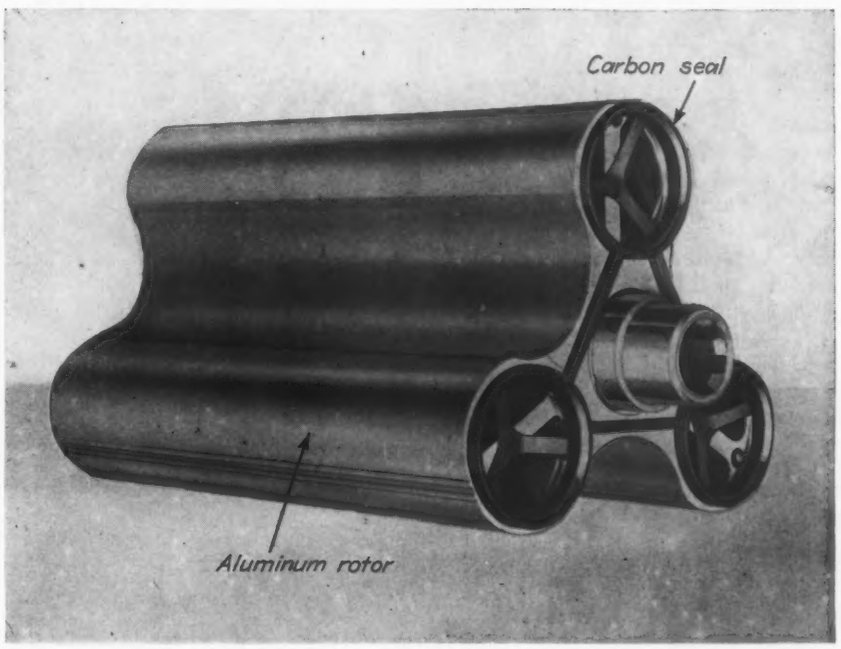
ORDNANCE REDESIGNS SAVE SCARCE METALS



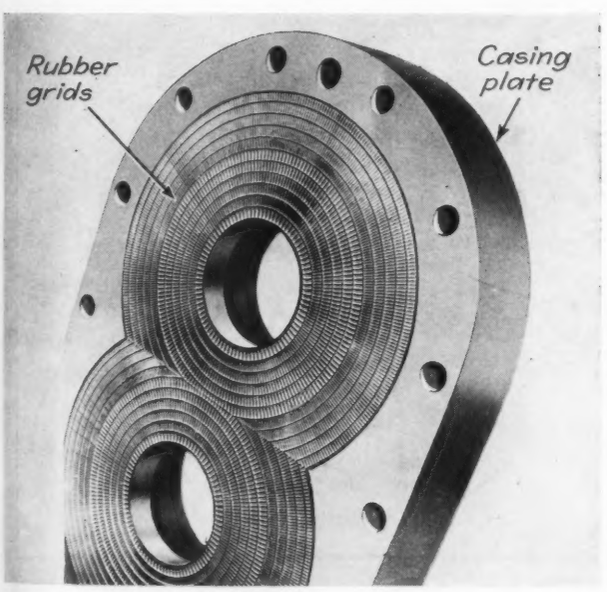
Die-castings of low-grade aluminum replaced scarce high-grade aluminum castings in these tail plugs and primer holders for incendiary bombs. Center redesign, also in low-grade aluminum, saved 40 percent in weight. A redesigned roller for machine gun belts is of injection-molded cellulose acetate butyrate, instead of die-cast aluminum.

CARBON AND MOLDED RUBBER SEAL BLOWER ROTORS

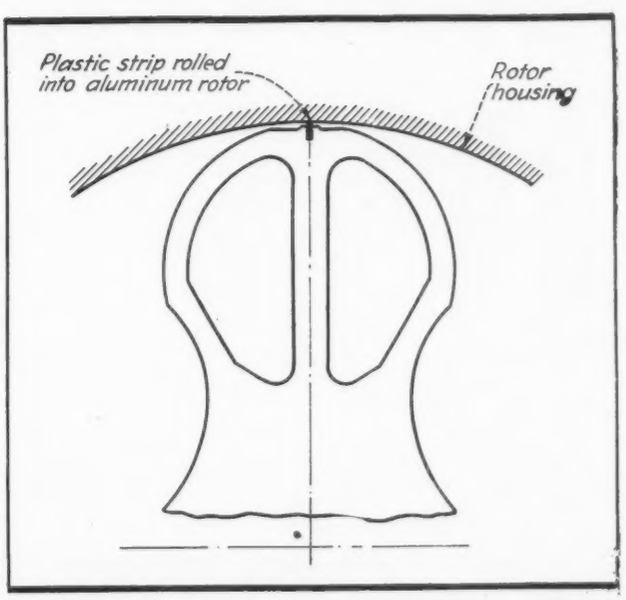
Two unique designs for reducing the leakage of air at ends of rotors in blowers and superchargers have been developed by engineers of the McCulloch Engineering Corporation. Both designs also eliminate any hazards that might result from the rotor ends seizing the casing plate because of slight misalignment that may be caused by distortion resulting from the differences in temperature between the discharge side and the intake side. Also on sudden load changes, the rotor heats and expands before the housing, causing reduction in running clearance.



Carbon seals, mounted on the end of aluminum rotors, are held in contact with the ground and polished surface of the iron end casting by light springs thus effectively reducing the end clearance. The play in the spring loaded seals permits the aluminum rotor to expand axially before the housing expands and yet prevent leakage. Under the light spring pressure the rate of wear on the carbon seals is low. No lubrication is used. The seals, similar to electric motor brushes, are of a hard carbon compound containing graphite and lead.



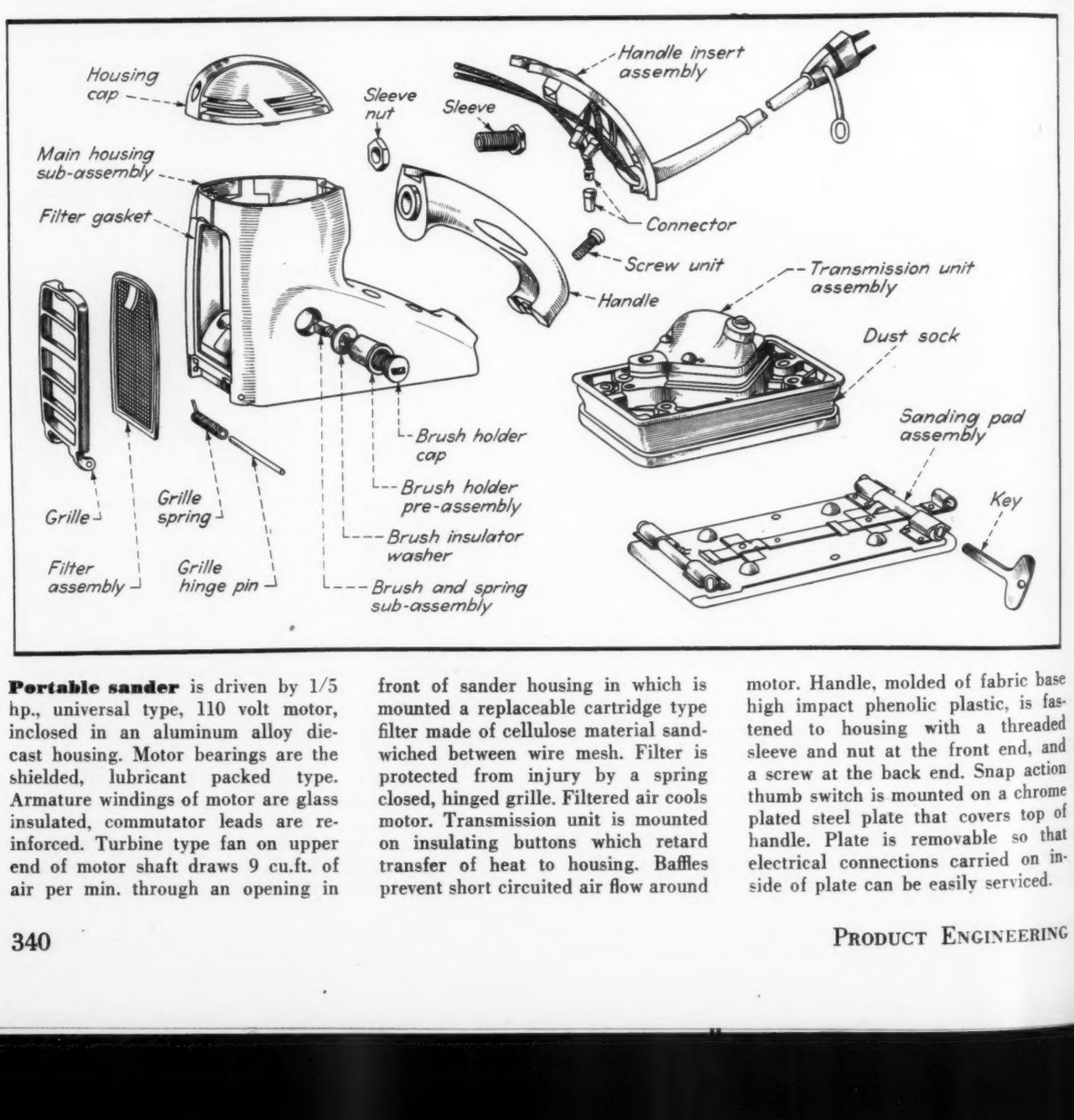
Molded rubber grids, in a second design, are bonded to the face of the end casting to provide a sealing surface. Ends of the rotors are roughened slightly by a fine knurling operation. When the blower is assembled, end clearance is adjusted so that the ends of the rotors are in contact with or very close to the tips of the edges of the rubber grids. In operation, as the rotor expands, the rubber wears away slightly and soon reaches a correct clearance. This wearing-in takes place in the shop test run.



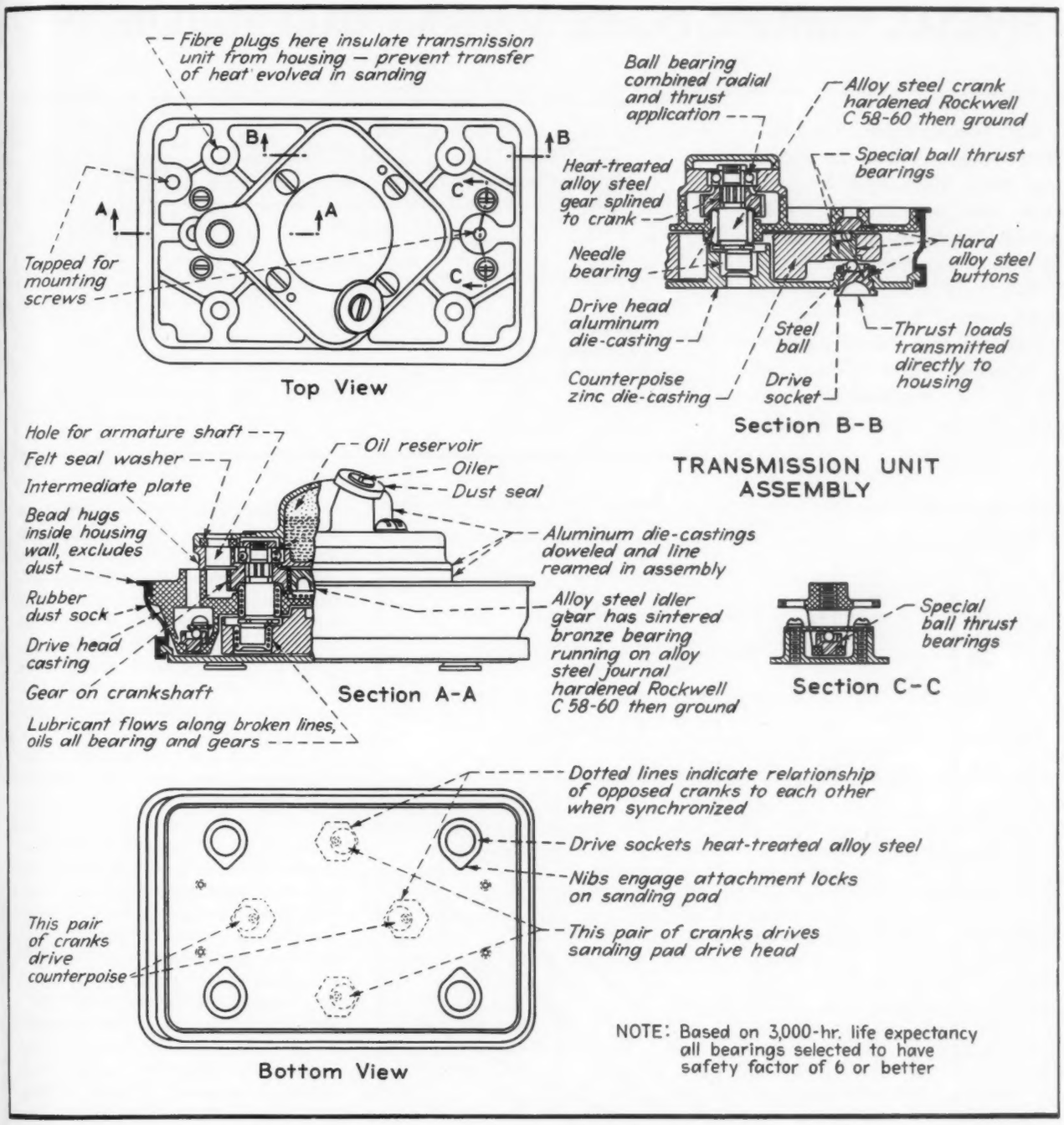
Plastic strip is rolled into a slot in the tip of each lobe of the rotor to reduce the clearance between the outside diameter of the rotor and the housing. After rolling in the strip, it is machined so that the clearance between the rotor and the housing bore will be practically zero. No excess clearance is required for safety. It has been found that the strip will wear into the correct operating clearance at the time of run-in. The arrangement has resulted in an increased volumetric efficiency in blower operation.

COUNTERPOISE CANCELS VIBRATION IN SANDER

With the objectives of eliminating physical fatigue and also of reducing time spent in various sanding, lapping and polishing operations now performed in war industries engaged in the manufacture of products made of wood, metal and plastics, the engineers of the Sterling Tool Products Company have developed and designed a portable electric sander for heavy production duty. Vibration is cancelled out by balancing the inertia forces in the oscillating head of the sander with forces generated in an opposed oscillating counterpoise driven by synchronized dual cranks. Gears and counterpoise mechanism are sealed in dust-proof cartridge type case. Sanding head oscillates 4,500 times per min. in a $\frac{3}{16}$ in. orbit.



Portable sander is driven by 1/5 hp., universal type, 110 volt motor, inclosed in an aluminum alloy die-cast housing. Motor bearings are the shielded, lubricant packed type. Armature windings of motor are glass insulated, commutator leads are reinforced. Turbine type fan on upper end of motor shaft draws 9 cu.ft. of air per min. through an opening in front of sander housing in which is mounted a replaceable cartridge type filter made of cellulose material sandwiched between wire mesh. Filter is protected from injury by a spring closed, hinged grille. Filtered air cools motor. Transmission unit is mounted on insulating buttons which retard transfer of heat to housing. Baffles prevent short circuited air flow around motor. Handle, molded of fabric base high impact phenolic plastic, is fastened to housing with a threaded sleeve and nut at the front end, and a screw at the back end. Snap action thumb switch is mounted on a chrome plated steel plate that covers top of handle. Plate is removable so that electrical connections carried on inside of plate can be easily serviced.


Fibre plugs here insulate transmission unit from housing — prevent transfer of heat evolved in sanding
Tapped for mounting screws
Top View
Ball bearing combined radial and thrust application
Alloy steel crank hardened Rockwell C 58-60 then ground
Special ball thrust bearings
Heat-treated alloy steel gear splined to crank
Needle bearing
Hard alloy steel buttons
Drive head aluminum die-casting
Steel ball
Thrust loads transmitted directly to housing
Counterpoise zinc die-casting
Drive socket
Section B-B
TRANSMISSION UNIT ASSEMBLY
Hole for armature shaft
Felt seal washer
Intermediate plate
Bead hugs inside housing wall, excludes dust
Rubber dust sock
Drive head casting
Gear on crankshaft
Lubricant flows along broken lines, oils all bearing and gears
Oil reservoir
Oiler
Dust seal
Aluminum die-castings doweled and line reamed in assembly
Alloy steel idler gear has sintered bronze bearing running on alloy steel journal hardened Rockwell C 58-60 then ground
Section A-A
Special ball thrust bearings
Section C-C
Dotted lines indicate relationship of opposed cranks to each other when synchronized
Drive sockets heat-treated alloy steel
Nibs engage attachment locks on sanding pad
This pair of cranks drives sanding pad drive head
This pair of cranks drive counterpoise
Bottom View
NOTE: Based on 3,000-hr. life expectancy all bearings selected to have safety factor of 6 or better

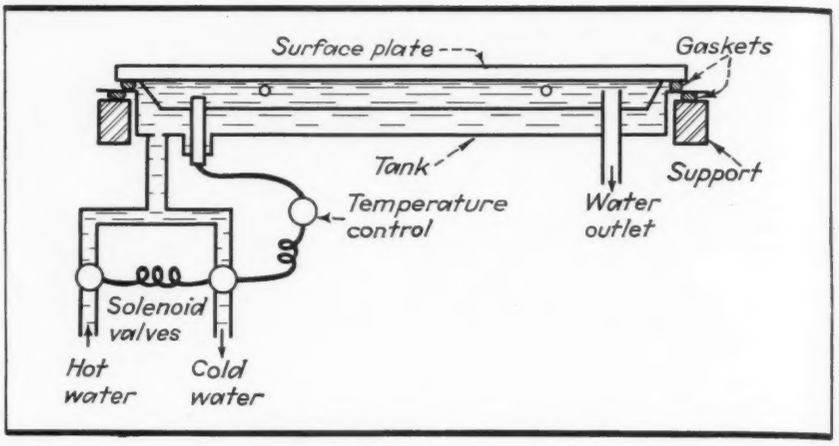
Transmission unit is sealed in a cartridge type case consisting of aluminum alloy die-cast top cover, intermediate bearing plate, main bearing plate and sanding pad drive head. Reservoir in top cover holds enough oil to lubricate the transmission for 100 hr. The gear train consists of an idler gear which turns on a hardened and ground alloy steel journal mounted at center of drive head, and four gears splined to the crankshafts that oscillate the sanding head and the zinc alloy die-cast counterpoise. Pinion cut on lower end of motor shafts mates with gear splined to front crankshaft. This gear drives the idler gear which in turn drives the gears on the other three crankshafts. Crankshafts are supported in ball bearings mounted in intermediate plate and by needle bearings mounted in main bearing plate as shown in Sections AA and BB. Crankshafts are synchronized and counterbalanced. In Section BB is shown one of the cranks that impart an orbital motion to the sanding pad drive head. In Section AA is shown one of the crankshafts, the inertia forces of which cancel the inertia forces of the sanding pad drive head. Ball bearings riding on hardened alloy steel buttons inserted in the drive casting, counterpoise casting and sanding pad drive head are provided to resist vertical thrust loads.

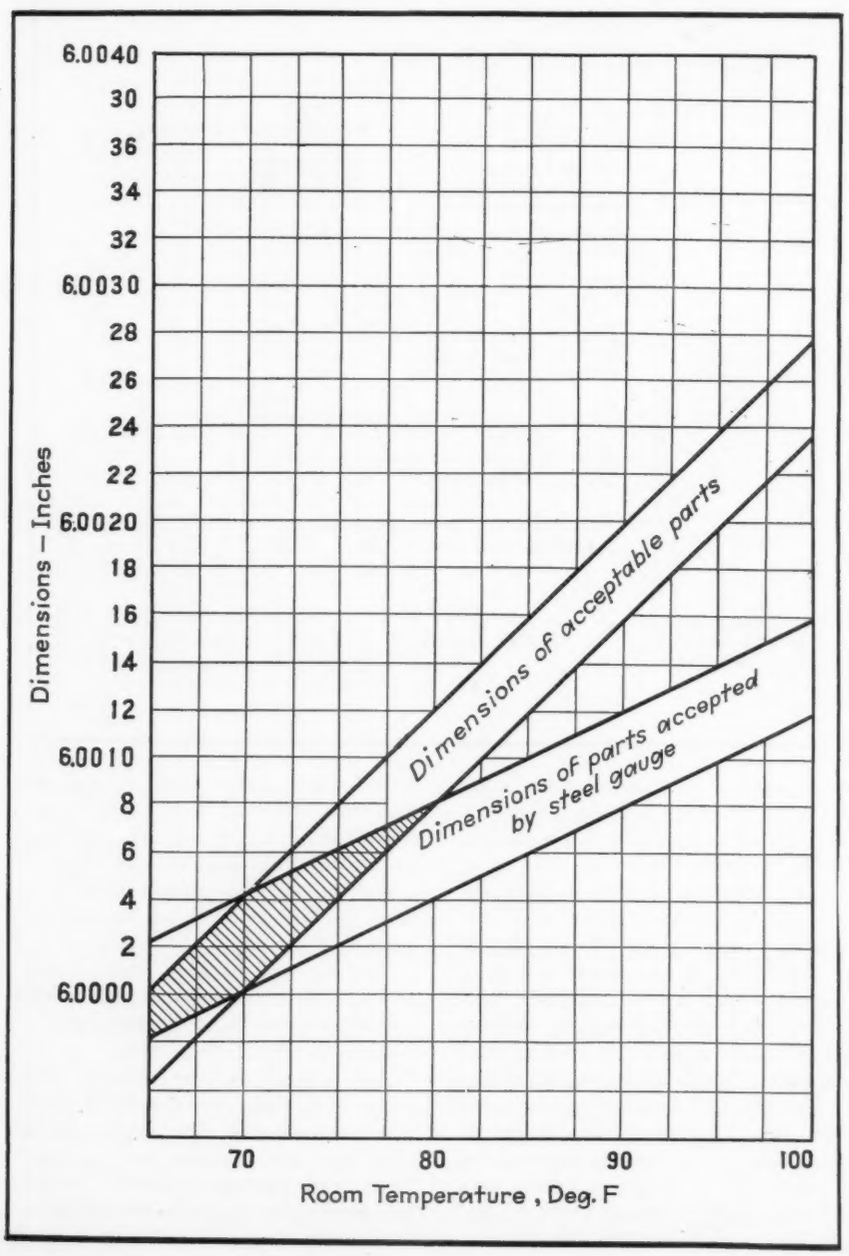
A molded rubber sock is snapped over and cemented to the main bearing plate and to the sanding pad drive head to exclude dust. Outside edge of a wide flat bead at top of rubber sock hugs the inside wall of housing to exclude dust.

Sanding pad backing plate, made of flexible spring steel has four spherical bosses which fit into sockets formed in the bottom faces of the thrust buttons in the sanding pad drive head. Nibs on the thrust buttons engage with side fingers on a slide bar attached to sanding pad plate. Pad attachment lock is easily operated by two fingers. When lock is pulled out, pad is detached.

SPECIAL SURFACE PLATE REDUCES GAGING REJECTS

Room temperature variation often causes rejects in aluminum parts measured by steel gages and standards. Union Special Machine, manufacturing aluminum parts 6.000 + 0.0004 — 0.0000 in. in size found that a 10-deg. temperature change caused all parts to be rejected when steel-gaged. Rejects led engineers to develop this special surface plate.



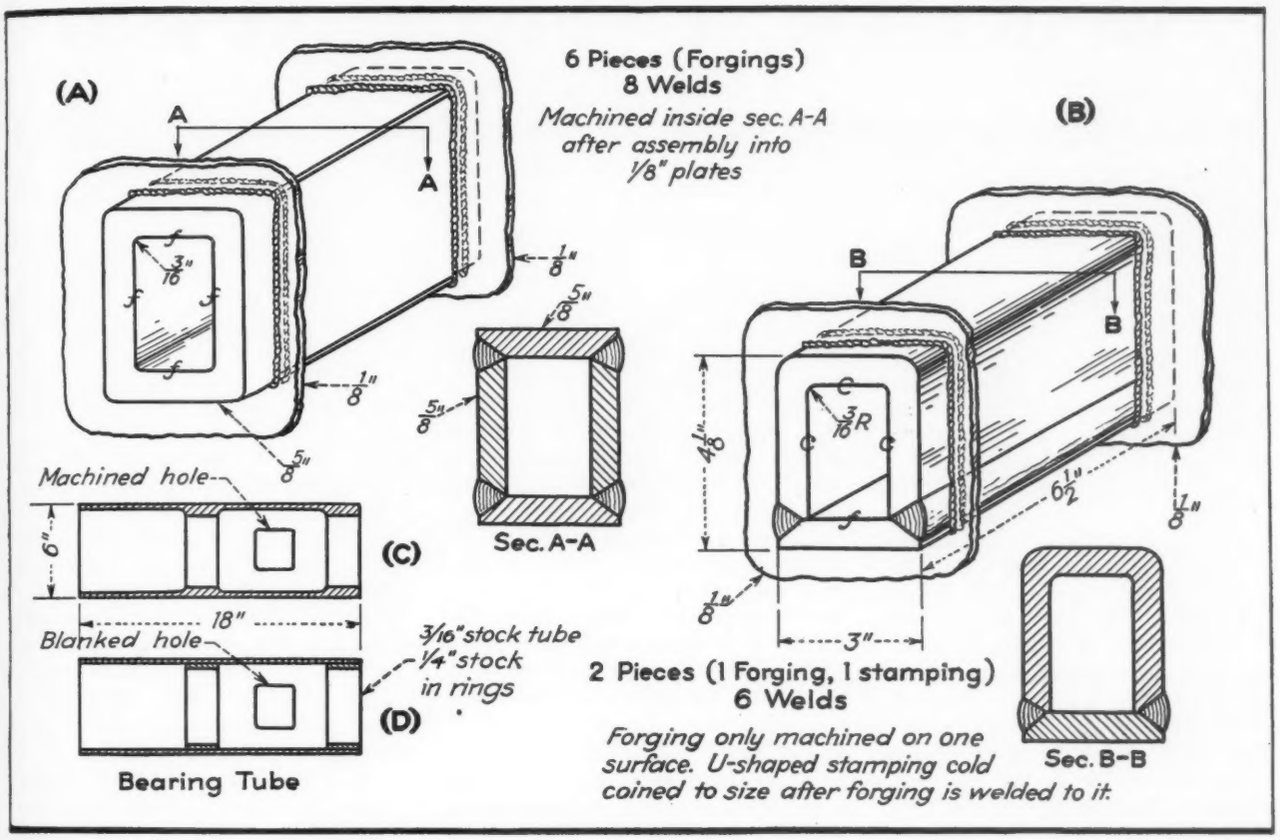


Constant - temperature surface plate can be used successfully even when temperature differential between plate and room is 25 deg. Design utilizes a tank of which the surface plate forms the top. Weight of plate on gasket is sufficient to prevent leakage. Tank is insulated from supports by gasket. Inlet water is sprayed into tank to prevent formation of hot and cold layers.

To prevent dew condensation on the plate and fixtures on muggy summer days, the temperature is set above the extreme dew point, usually at 75 to 80 deg. F. Parts gaged must naturally be close to the gaging temperature. Aluminum parts fresh from machining may be half an hour or more in reaching room temperature. If placed in good contact with the plate or fixtures on the plate, or immersed in a bath, they will assume the correct temperature in a few minutes. Water alone will cause rusting of the fixtures, but parts can be immersed instead in kerosene or other solvent, or a soluble oil-water emulsion contained in a tank surrounded by the overflow water.

Effect of temperature variation on acceptance of aluminum parts, 6.0000 in. in diameter + 0.0004 — 0.0000 in size, as determined (left) in laboratory of Union Special Machine. Measurements were made with dial indicators calibrated by steel standard that measured 6.0000 in. at 70 deg. F.

REDESIGNS REDUCE WELDING AND MACHINING



Pin bracket shown at *A* was originally made by arc welding four 5/8 in. thick forgings along their edges thus forming a short column of box sections. This column was then welded in place between two 1/8 in. thick plates, after which a square ring forging was arc welded on each side plate opposite the ends of the column. This assembly, consisting of 6 forged pieces held together by 8 welded joints, was then machined.

In new design shown at *B*, developed by the engineers of Midland Steel Products Company, only one forging and one stamping are used, and there are only 6 joints to be welded. The column is made by welding a flat forging to a U-shaped stamping, the latter then being cold coined to size. The column is made long enough to project through the side plates. Only machining required is on the surface of the forging, which forms part of the inside wall.

Bearing tube was formerly machined out of heavy wall seamless tubing as shown at *C*. To save material and machine time, the bearing tube was redesigned as shown at *D*. In the new design two rings are made by blanking and forming, after which the ends are welded and the ring sized in a die. The rings are then put into a fixture and an open seam tube, which has been formed in presses, slipped over them. After clamping parts in position, the longitudinal seam of the tube is welded. After welding the tube shrinks or contracts over the rings. The rings are then spot welded to the outer shell.

REDESIGN CHALLENGES TO ENGINEERS

FINS for 500 lb. bombs might be designed to fold flat yet permit easy assembly overseas. On the next million, because the crate would be practically eliminated, three new Liberty Ships would be literally created out of thin air by the saving in shipping space. Steel saved by eliminating present crate would be enough to build another ship.

The third Dispatch from the production front in the "Tremendous Trifles" series published by U. S. Army Ordnance, entitled "Battlenecks," lists some more challenges. Here are a few:

HOW MANY specifications call for unnecessarily high physical requirements that force the use of high alloy steels?

TWENTY-NINE critical machine operations were replaced by seven noncritical operations in the 20 mm. cannon trigger coverplate. Similar savings can be recorded by the man who redesigns the .30 calibre carbine trigger guard, and a machine gun receiver. Although the latter weighs only 5 lb., it is at present being machined from a 23 lb. forging, wasteful of both machining time and material. Such a redesign would release machine tools and skilled labor.

IF CENTRIFUGAL CASTING permits lower alloy steel in tank sprockets, what about other sprockets and gears?

WARTIME DESIGN NEWS

25 YEARS OF ORDNANCE PROGRESS:

The Ordnance Department has been telling the country that it has done a good job in establishing the weapons of this war, and a run through the record since Dec. 8, 1941, lends considerable support to that claim. It did another noteworthy job recently in bolstering its claim by comparing the weapons of World War I with the weapons of this. Starting with the infantryman's rifle and working up through the heaviest of guns, the comparison shows startling progress.

In World War I, the doughboy was armed with the 1903 Springfield rifle which fired five shots. Today's M1 Garand fires eight in the time the Springfield fired three and needs no manual bolt operation. In 1918, the infantry fought principally with rifles and bayonets, with few automatic and anti-tank weapons. Today it fights with automatic rifles, bayonets, light and heavy machine guns of three types, mortars and self-propelled anti-tank guns. The Garand alone is credited with tripling the infantryman's fire power.

In 1918, each infantry regiment had 12 Vickers light machine guns, one to each 300 riflemen. The Vickers was "undependable," subject to complicated stoppages which were not quickly reduced. An infantry regiment today has 12 light and 24 heavy machine guns, or one for each 84 men, including the .50-caliber gun which fires a slug as big as your thumb. Stoppages are easy to eliminate. If automatic rifles were available in 1918, they were Lewis or Chauchat rifles, one to a squad. Today there are plenty of Browning automatic rifles more efficient, sturdy and accurate than either the Lewis or Chauchat.

Heavy Weapons Now Plentiful

Twenty-five years ago, the troops were short of heavy, accompanying weapons, depending to a large degree on the smooth-bore Stokes mortar. There were four to a regiment, firing shells which landed where the wind allowed them to land. Today, there are nine 60-mm. and 12 81-mm. mortars to a regiment, accurate to more than 2,000 and 3,000 yd, respectively, the latter firing a shell whose destructive effect approximates that of the 105-mm. howitzer. Today, there is one mortar to every 144 men in an infantry regiment. In the last war, it was one to 900 men.

In 1918, we landed in France without any anti-tank guns, obtaining from the French four 37-mm. guns per regiment. These "one-pounders" fired a high-explosive shell accurately about 1,800 yd. Today, despite the existence of a highly-mobile 37-mm. gun which is accurate to a greater range and which possesses greater firepower, our principal anti-tank weapon is a self-propelled 3-in. gun (PRODUCT ENGINEERING, April, p. 193) which fires 25 aimed shots a minute, accurate at more than 8 mi., battle-tested on German tanks, which it stopped.

In World War I, the principal artillery piece used by U. S. troops was the French 75-mm. gun, of which several vastly-improved models exist today. It has been replaced however, by the 105-mm. howitzer firing a shell twice as heavy as the World War I 75-mm. shell and with twice the fire power. It operates from a self-propelled mount. Some French 155-mm. howitzers were used in the last war, replaced today by U. S. 155's which move on self-propelled mounts or

Photo by U. S. Army Signal Corps

Captured intact at a North African airport was this German Heinkel H-3 bomber. The plane and the hangar behind it appear to be essentially undamaged, in contravention of the military principle which demands that materiel always be destroyed rather than left undamaged for the benefit of the enemy.

Official U. S. Army Photo

Mobility of a medium tank is given the Army's 155-mm howitzer by mounting it on an M-3 tank chassis. It is called "Juggernaught," and is more accurately known as the M-12 gun motor carriage. The gun's 95-lb. projectile can be fired 10 mi. It can knock out any known tank or even sink a heavy cruiser at that range. Its mobility gives the field commander a higher fire potential more rapidly than it could be obtained in any other way. Here the "Juggernaught" is shown dug into position, ready for action.

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wheeled mounts which can be moved at 60 m.p.h. The 1943 model outranges the 1918 howitzer by nearly 50 percent.

For siege purposes or other heavy duty, troops in the last war had the British 9.2 siege howitzer, replaced in this war by the 240-mm. howitzer, (PRODUCT ENGINEERING, May, p. 273). The 240 fires a shell 20 percent heavier than that of the 9.2 to twice the range. Accuracy of the 240 "has never been excelled."

Variety of Anti-Aircraft Guns

Anti-aircraft guns of the first World War were mostly improvised, with Lewis or Hotchkiss machine guns mounted on wagon wheels to fire rifle bullets, or with 75-mm. or 3-in. guns firing high explosive or shrapnel. Hits even on the slow aircraft of the last war, some of which flew at today's landing speeds, were rare. That's all changed today, as some of the Japs who flew over Corregidor can testify. Starting with the .50-caliber machine gun on special anti-aircraft mounts, the list of anti-aircraft guns runs through the 20-mm. Oerlikon gun, the 37-mm. cannon, the 40-mm. Bofors gun (PRODUCT ENGINEERING, Jan., p. 5) and the 90-mm. gun (PRODUCT ENGINEERING, Oct., 1942, p. 55), accurate thousands of feet up. These guns are controlled by an instrument which requires only that its operators keep the target within the cross hairs while it computes complicated firing data.

Both the 90- and 40-mm. guns are dual purpose weapons which can be lowered to horizontal for firing at armored vehicles. In this capacity, as well as in its anti-aircraft application, the 90-mm. gun is superior to the German 88-mm. gun, (PRODUCT ENGINEERING, March, p. 129).

DIE CASTERS CERTIFIED:

WPB's program for the inspection of die-casting facilities (PRODUCT ENGINEERING, March, p. 130), aimed at disclosing producers who can do high-precision work for the armed services, is well under way. Plants of 23 die casters, representing well over 60 percent of the industry, are now being inspected, and before July 1 it is believed that all recommendations will be in.

Recommendations as to certification or disapproval will be made to Harvey A. Anderson, deputy director of the Conservation Division, and government presiding officer of the Die-Casting Industry Advisory Committee, who will certify satisfactory plants to the armed services as qualified producers of special-quality zinc or aluminum die castings.

Orders for special-quality castings should not be placed indiscriminately by the services, since they are more expensive and difficult to produce than the usual commercial castings, which are suitable for many military applications. The Technical Subcommittee of the Die-Casting Industry Advisory Committee, under the chairmanship of D. L. Colwell, of WPB's Conservation Division, is available to judge contemplated special-quality rating of individual castings to prevent swamping of certified facilities.

Requirements Were Rigid

Qualifications demanded of die casters for certification are rigid. Both aluminum and zinc die casters are required to have "readily available" X-ray equipment of 140-kv. or greater capacity, and must agree to use it in accordance with instructions of the purchaser. Physical testing facilities must be adequate, and must include a standard A.S.T.M. test bar die, a tensile machine and an impact machine. Producers must evidence "adequate engineering and mechanical ability, skill and experience for design of critical die-cast parts," and must "show evidence of methods of handling scrap and other materials so that physical properties and limits of specifications can be met."

In addition, aluminum die casters must agree to supply castings equivalent to A.S.T.M. specification ES-29 for "Special-Quality Aluminum Die Castings (Pressure Molded Castings)" for critical applications and demonstrate their ability to do so. They must also have available high-pressure cold chamber equipment of approved design and construction.

Zinc die casters must agree to pro-

duce castings equivalent to A.S.T.M. specification B186-43T for "Special-Grade Zinc-Base Alloy Die Castings" for critical applications and demonstrate their ability to do so. They may neither produce nor process lead- or tin-bearing products except in separate buildings located some distance from the place where zinc-base die castings are produced or processed. They must also have available spectrographic equipment of approved design and demonstrate ability to control composition to the rigid limits required.

Separate Certification

Certifications for aluminum and zinc die castings are made separately in view of the varying requirements. No spectrographic examination of aluminum castings is required, but both X-ray and spectrographic examinations of zinc-base castings are obligatory. The committee is also examining facilities for magnesium-alloy die casting.

Rigid production controls and inspection methods are required of both types of producers.

Members of the Die-Casting Plant Inspection Committee are David Basch, chairman, General Electric Co.; R. W. Waring, Sperry Gyroscope Co.; C. E. Heussner, Chrysler Corporation; and J. R. Townsend, Bell Telephone Laboratories.

MAGNESIUM COMES IN:

It is not sufficiently plentiful to be used indiscriminately, but magnesium has loosened sufficiently to allow wider use of the metal in military equipment where it will improve performance. Particularly in airborne or handborne equipment can the use of magnesium now be considered.

For the first time in months, magnesium was not carried at the top of the list of the most critical non-ferrous metals in the Material Substitutions and Supply List No. 8, promulgated by WPB's Conservation Division. It dropped to fifth place, behind aluminum, cadmium, bismuth and tin. Only copper and zinc, in that order, are less critical than magnesium in the list of extremely critical non-ferrous metals.

This easing does not apply to all fabricated forms, particularly sheet and extrusions, but on the strength of it, facilities for die, sand and permanent mold castings of magnesium are being increased. As a result of this capacity boost, WPB plans to apply its certification program for special high-precision die casting to the magnesium die-casters.

LUMBER GETS WORSE:

Estimated 1943 demands for lumber are set at 31,500,000,000 b.ft. Production goal was set at 32,000,000,000 b.ft. First-quarter production returns indicate an output this year of slightly less than 30,000,000,000 b.ft. Loss of manpower, inclement weather, lack of equipment, increased use and widespread substitution for metals are given as the reasons for the tightening supply situation.

That, briefly, is the lumber outlook as this issue goes to press. WPB officials feel that 50 percent of the year's requirements may be needed for boxing and crating. These uses will offset the drop of approximately 10,000,000,000 b.ft. for construction this year.

Meanwhile, new specifications and grading rules were issued for yellow poplar aircraft lumber in order M-279 as amended, and WPB's Lumber and Lumber Products Division laid plans to boost output of softwood plywood to meet large increases in requirements. Army Air Forces are expected to require 300,000,000 sq.ft. of this material for the rest of the year. First-quarter production was 30 percent below that for the corresponding quarter last year.

MATERIALS:

Copper, nickel, synthetic plastics and aluminum used in safety equipment are eased by amendment of Appendix A to Order L-114 as amended. Among other changes, aluminum may be used in machine guards where a less scare material is not practicable.

Seven species of western lumber (Ponderosa, sugar, Idaho white and lodgepole pines, white fir and Englemann and western white spruces) are restricted almost completely to military use by Order L-290. Civilian allocations of this lumber will be made on form PD-872.

Copper and copper-base alloys may no longer be used in the manufacture of certain wiring devices under Order L-277. Wiring devices are defined as current-carrying parts which do not consume energy but are used for switching, tapping or connecting.

Acrylic-resin scrap is no longer under restriction as to use, processing, delivery or acceptance under an amendment to Order L-260. The amendment does not affect restrictions on acrylic monomer and acrylic resin.

Adhesives for hardwood plywood have become critical and only those manufacturers engaged in direct war work will be given consideration under allocation, WPB warned. New requirements for commercial grades of plywood for the Army Air Forces will take all the capacity of the industry and will require conversion of several mills still not on war work.

Vulcanized fibre for non-essential civilian uses is curtailed by order M-305, which allocates the material for certain uses.

Vinyl polymers for experimental purposes may be accepted in the amount of 50 lb. monthly without specific authorization by WPB under an amendment to Order M-10.

Steel, iron, aluminum and other critical materials for use on hand trucks and related handling equipment are restricted under Order L-111 as amended.

Copper for automotive maintenance equipment is placed under control by Order M-270 as amended. Restrictions are identical with those applying to steel, aluminum and other critical materials for the same use. Under the amended order, copper may not be used for this equipment where use of a less critical material is practicable.

Ethyl cellulose restrictions have been tightened by issuance of Order M-175, as amended. The 50-lb. exemption for small orders was reduced to 10 lb., and an exemption of 50 lb. per month was allowed for experimental purposes. All other allocations of the material must have specific WPB authorization on forms PD-600 and PD-601.

Copper and zinc for plumbing fixture fittings and trim are further restricted under Schedule V, as amended, of Order L-42.

Cellulose acetate is becoming more critical. Possibility of allocation control for this material has been discussed by WPB and manufacturers, who agreed that some form of control is necessary.

Phenolic-resin allocation changes were approved by industry representatives who reported that deliveries of their basic raw materials have improved so far this year.

Urea-resin war requirements are being satisfied except for special dry adhesives. Certain marginal civilian uses of this material probably face curtailment however.

No One Material Can Be 'Best'

"WHAT MATERIALS WILL BE USED most extensively after the war?" This is one of the most frequently asked questions today. Newspapers and popular magazines glorify plastics. Because the waters of the oceans contain a virtually unlimited amount of magnesium, some people prophesy this to be the "coming metal." Tremendously increased production capacity leads others to expect that aluminum will displace steel to an overwhelming extent. All of these glowing prophesies or dire predictions fail to take into consideration certain essential factors that determine which material or materials the designer will select, and ignore the changed techniques in engineering design with reference to the use of materials.

The engineering problem in the selection of a material can be broken down into four elements: (1) The material selected must possess the properties and qualities required for the uses to which it is to be put; (2) the material must be workable; (3) the properties and structure of the material must be stable; (4) the cost of the finished structure, as compared to that of using other materials, must be favorable.

Because none of these elements can be measured and expressed in numbers it is impossible to establish index figures indicating the relative merits, based on these elements, of various materials. Even strength values are in themselves meaningless because the ability of material to resist forces is determined by the composite value of many of its properties, some of which are not even measurable.

Workability of a material today is usually evaluated by comparison with other materials. Recently introduced processes and improved manufacturing operations indicate how swiftly the relative workability of a material changes. Powdered metal pressings, electrostatic heating, induction heating and new gluing methods are examples of fabricating techniques that have altered the materials picture drastically. The present workability of a material cannot serve as a premise in judging its future usefulness.

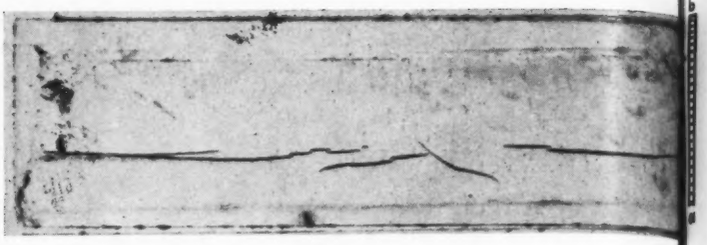
Tremendous progress has been made in increasing the stability of materials. New alloys and plastic compounds, heat-treatments, cold-working techniques, corrosion inhibitors and protective coatings have revolutionized the possibilities in the fields of use for many materials. They increase the stability of their structure and properties, and maintain these properties over wide ranges of temperature and humidity.

The price of various materials after the war is anybody's guess. Presumably, there will be little change in the base price of carbon steel, but it is safe to assume that metallurgical developments will have a marked effect on the cost of alloys. Increased capacity and improvements in production technique tend to lower still further the price of aluminum, but the ingot price might possibly be pegged around present levels in order to protect government-financed plants. It is safe to assume that the price of many of the plastics will come down, such being the normal price trend for all new materials.

Besides all of these considerations, one must also reckon with the new design philosophy that has developed over the past decade. Designers are now extremely choosey in selecting materials. Different members of the same structure are often made of different materials, and even a single member may be composed of several different materials. Dozens of combinations are enabling designers to achieve remarkable results. Mechanical mixtures are now being used by designers to enhance further the effectiveness of chemical compounding, which includes alloys.

All in all, no one material can possibly dominate the post-war market, but the materials that engineers know how to use most effectively will be favored.

G. F. Nordenholt.



Effects of Residual Stress On the Fatigue of Metals

J. O. ALMEN
Research Laboratories Division, General Motors Corporation

Design, metallurgical and production engineers are jointly responsible for improving efficiency in the use of materials and the fatigue life of machine parts. This article describes some of the shortcomings in current design concepts, testing procedures and manufacturing methods that should be corrected by giving serious consideration to residual stresses and their distribution.

OF ALL fatigue hazards, residual stresses of the wrong kind are perhaps the most insidious, because an engineer can seldom know their intensity, the pattern in which they are distributed within the material or whether they are alike for all commercially identical machine parts. Residual stresses may result from the conditions of operation. In brake drums, clutch plates or other friction surfaces the instantaneous temperature in a thin layer may be so high that under thermal expansion the surface layer is stressed beyond the yield point in compression. Then when the source of heat is removed, and the hot surface layer is quenched by the underlying adjacent cool metal, the tension stresses caused by thermal contraction are so severe that fractures often occur in the surface layer.

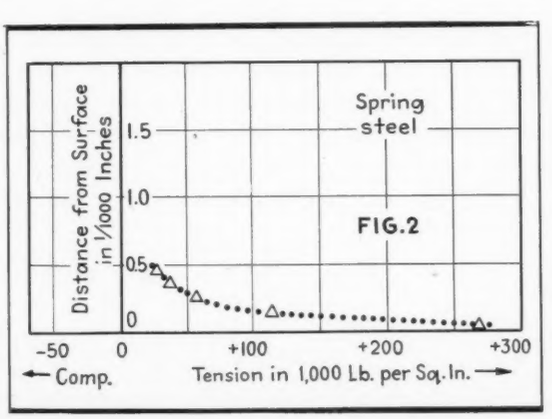
Efforts to improve products by improving their surface finish may sometimes have an effect opposite to that desired. Highly finished surfaces and fillets may lead to a false sense of security if, as the result of machining or straightening operations, the parts have had set-up in them high residual stresses of the wrong kind.

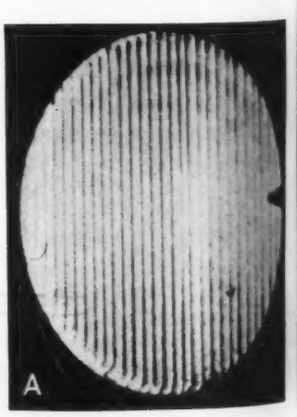
Based on test observations, it is the author's opinion that, from the standpoint of fatigue strength, more harm than good often results from the grinding of machine parts. Surface tension stresses from grinding are often great enough to produce visible or Magnaflux surface cracks. But, whether detectable or not, surface tension is frequently serious. Fig. 1 is a reproduction of a Magnaflux transfer print on transparent cellulose tape showing surface fractures in a ground gear tooth. This tooth failed by spalling that originated in these surface fractures. Fatigue cracks start on the side of the gear tooth that is loaded in tension, and the effective stress in the surface of the tooth is the stress which remains after grinding plus the working stress.

The intensity of surface tension stress in a specimen that was ground in accordance with normal commercial practice is shown in Fig. 2. The specimen was annealed spring stock $\frac{1}{16}$ in. thick, 1 in. wide and 7 in. long, it was ground to a depth of 0.002 in. Originally straight, the specimen after grinding was found to be curved concave on the ground side thus indicating a tension stress in the surface on the ground side. Very thin layers were then removed from the ground surface by hand honing until the specimen regained its initial straightness. Measurements of the change in curvature after each thin layer was removed permitted calculation of the stress distribution in the ground surface. Obviously a stress of 270,000 lb. per sq. in., which is slightly below the fracture point of full hard steel, could not be supported by the steel in the annealed state. From this it follows that the stressed layer was hardened by the heat cycle of the grinding operation to not less than Rockwell 55 C. The extreme thinness of the hardened layer presents an interesting problem in hardness measurement. The apparent hardness of the spring steel specimen measured by usual methods was

	Unground	Ground
Rockwell B	88	89
Rockwell C	5	5
Vickers Brinell	193	199

A comparison of the hardness readings shown in the table with the cal-





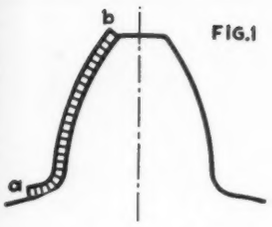


Fig. 1—Surface fractures in a gear tooth that was overstressed during the finish grinding operation

culated stresses demonstrates the futility of the normal hardness measuring technique for determining the hardness of the most significant portion of machined parts, the surface layer.

Residual stresses often result from the cooling of castings and forgings or from the vigorous heat transfer of heat-treating. Also many parts, such as crankshafts, axle shafts, and camshafts require straightening during processing, and when the operation is done at room temperature without subsequent stress relieving, the result is the introduction of severe residual stresses in the part.

When metal cutting has been unusually severe, it is often found that the surfaces are fractured. Finish machining or grinding rarely go deep enough to remove the metal stressed by previous rough machining and, of course, these finishing operations add stresses of their own. Whenever it is economically practicable, residual stresses that produce tension in any surface layer subjected to cyclic tension stress should be reduced or removed or, better still, converted to compressive stress by suitable treatment, because all fatigue failures are caused by tension stresses.

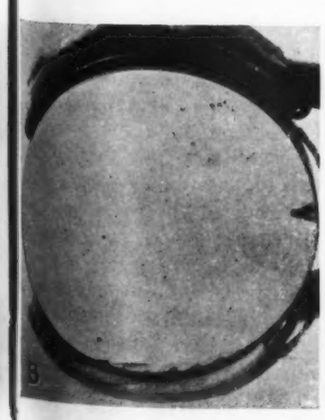
In connection with the damage that can be done by machining, an interesting and perhaps important observation has recently been made which indicates that the layer "injured" by machining is deeper than is generally believed. The observation also shows that the "injured" material does not recover when heated for long periods at high temperatures. Fig. 3(*A*) shows the surface of a bar of 4615 steel as it appeared after rough machining on a shaper. This piece was then carburized for 8 hr. at 1,700 deg. F., cooled in the box, reheated to 1,500 deg. F., quenched in oil and drawn at 300 deg. F. for one hour. The machined surface was then ground in a direction at right angles to the shaper marks to a depth of 0.0055 in. below the last visible tool mark. After grinding, the surface was polished and appeared as shown in Fig. 3(*B*). Finally, the polished surface was shot blasted, whereupon the machining marks (vertical lines) and the grinder marks (horizontal lines) reappeared as shown in Fig. 3(*C*), thus indicating that the material was not uniform in resisting the shot blasting notwithstanding the long period at elevated temperature. There is no evidence at present that the effect brought out by this experiment is significant in fatigue. It is presented here merely to emphasize that there is much that is not known about materials and processes.

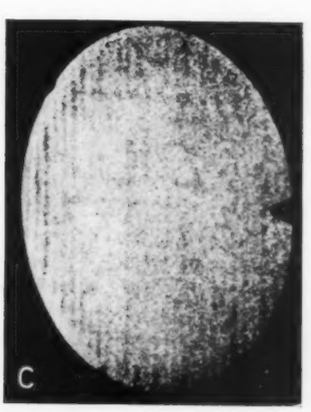
Surfaces of repeatedly stressed specimens, no matter how perfectly they are finished, are much more vulnerable to fatigue than the deeper layers. It has long been appreciated that the vulnerability to fatigue increases as the surface roughness is increased, particularly if the roughness consists of sharp notches and more particularly if the notches are oriented at right angles to the principal stress. The practice of carefully finishing fatigue test specimens is, of course, a recognition of this vulnerability insofar as visible marks or scratches are concerned, even down to assuring that the final polishing marks are parallel to the direction of the applied stress. These precautions are known to be effective in increasing the fatigue strength of the specimens. Specimens finished in this manner have, therefore, come to be known as "par" bars. This name implies that fatigue specimens approaching perfection in finish give the highest possible fatigue endurance for any particular material.

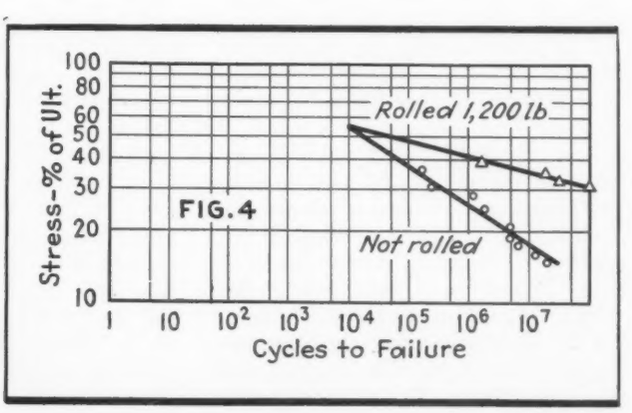
It can be shown, however, that the so-called "par" bars are not the best specimens and that influences akin to notches, so far as fatigue vulnerability is concerned, are retained by the "par" specimens. It seems that the specimen surface is highly vulnerable simply because it is a surface and that there is an extra hazard in the surface layer not shared by the deeper layers. This extra surface hazard may arise from sub-microscopic notch effects or from the fact that the surface is a discontinuity since the outer crystals are not supported on their outer faces.

The fatigue strength of the most carefully prepared specimen will be increased if a thin surface of the specimen is pre-stressed in compression by a peening operation such as peen hammering, swaging, shot blasting, tumbling or by pressure operations by balls or rollers. (See "Das Druken der Oberflache von Bauteilen Aus," *Stahl and Eisen*, O. Foppl, Vol. 49, 1929, p. 575). This increase in fatigue strength resulting from the surface layer being stressed in compression is clearly shown by the

Fig. 2—Residual stress in the outer layer of a ground spring steel specimen. Fig. 3 (A)—Rough machined surface of steel bar. (B)—Same surface polished after carburizing, quenching, and grinding to a depth of 0.0055 in. below last visible tool mark. (C)—Polished surface after shot blasting. Fig. 4—Stress-cycle curves for normally finished railway axles and for axles subjected to a rolling operation







stress-cycle curves, Fig. 4, which compare normally finished railway axles with axles that had been subjected to a rolling operation (See *A.S.M.E. Trans.*, Vol. 58, 1936, pp. A-91 to 98, "Increasing the Fatigue Strength of Press-Fitted Axle Assemblies by Surface Rolling," O. J. Horger and J. L. Maulbetsch. These and other tests show that the compression stressed surface is effective whether applied to highly finished specimens or to specimens having rough surfaces.

Most engineers are familiar with the improvement in fatigue that may be obtained by a few cycles of overload in parts such as springs. Local stresses from the overloads exceed the elastic limit of the material causing local yielding and, therefore, the tension stress at the working load is decreased. This treatment is the equivalent of rolling or peening, since in the unloaded state the member is stressed in compression in the areas where tension yield occurred during the overloading.

The most plausible explanation (see "Die Wirkong von Eigenspannungen auf die Biegschwingungsfestigkeit," H. Bugler and H. Bucholtz, *Stahl und Eisen*, Vol. 53, Dec. 1933, p. 1330) of the effectiveness of surface compression stress is that when a load is applied to specimens so pre-stressed, the stress in the surface layer is the resultant of the tension stress and the compression stress caused by pre-stressing, and since fatigue failure starts only from resultant tension stress the fatigue durability of the surface layer is increased. The tension stress in the material below the pre-stressed layer is not reduced but may be actually increased, notwithstanding which the fatigue strength of the specimen is increased. It follows, therefore, that the lower layer is inherently stronger than the surface layer. Foppl (see "Cold Rolling Raises Fatigue or Endurance Limit," S. G. von Heydekamp, *Iron Age*, Vol. 1, 126, Sept. 18, 1930, p. 775) shows that the fracture in rolled specimens does not originate at the surface but in the material below the pre-stressed layer as would be expected if the surface is sufficiently pre-stressed in compression.

The explanation can perhaps be clarified by use of the conventional textbook stress diagram shown in Fig. 5, for a beam supported at the ends and loaded in the central plane, PP_1. The stress at any point in the plane PP_1 of the beam is measured by the horizontal distance from the point in the plane to the diagonal line $T_1\ C_1$. Distance PC_1 represents the compression stress at the upper surface. Stress at the neutral axis OO is zero. Tension at the lower surface is represented by the distance $P_1\ T_1$. While this is a satisfactory stress diagram for static loads, it does not agree with the fatigue specimens. If the diagram Fig. 5 is modified to that shown in Fig. 6 in which T_1T_2 represents an added increment of tension stress, a reasonable representation of the surface fatigue vulnerability is obtained. For a sharply notched surface the additional stress increment T_1T_2 is relatively great. As the surface roughness is decreased the increment T_1T_2 decreases, but no matter how well polished the specimen may be, there still remains a considerable additional surface stress as measured by fatigue tests.

The diagram shown in Fig. 7 represents the stress pattern in an unloaded beam that has been rolled or peened, PC_2 and $P'C'_2$ represent the intensity of the tension pre-stress to balance the compression stresses in the surfaces. After this beam has been loaded from either side through one stress cycle, as in a reversed fatigue test, the compression pre-stress will be reduced if the applied load raises the total compression stress above the yield point. The stress diagram for such pre-stressed beam supporting an external load is shown in Fig. 8, in which the effective fatigue tension stress $P'T_4$ at the surface may be less than the stress T_5 below the surface in which event failure would start below the surface as noted by Foppl. Note also that the neutral axis is displaced from the geometric center of the beam and that the tension stress T_5 below the surface is greater than in the beam that had not been pre-stressed as shown by dotted lines.

It seems evident that the improvement in fatigue strength by compressive pre-stress is accounted for by the reduction in tension stress in the vulnerable surface layer. Also, that the increased compressive stress in a specimen stressed from zero to a maximum in either direction does no harm.

Further evidence of the extra vulnerability of the surface layer is found in the behavior of specimens having increased strength in a thin surface layer as in thinly carburized or in thinly nitrided specimens. Fatigue failures in such specimens also start below the surface and show

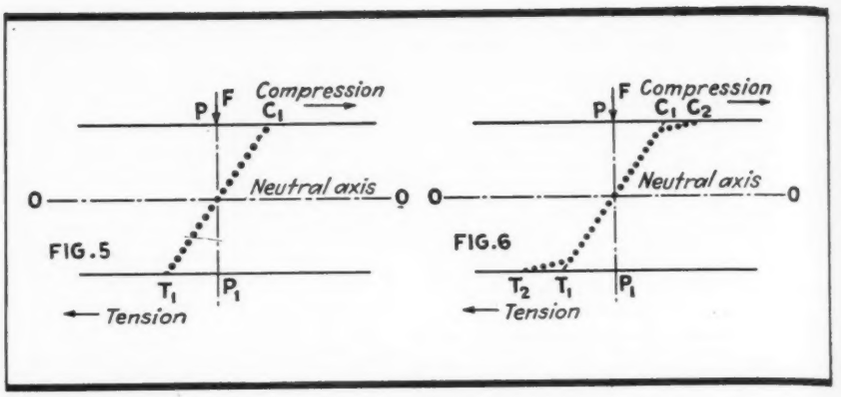


Fig. 5—Conventional stress diagram for a simple beam loaded at the center. Fig. 6—Modified stress diagram showing surface vulnerability

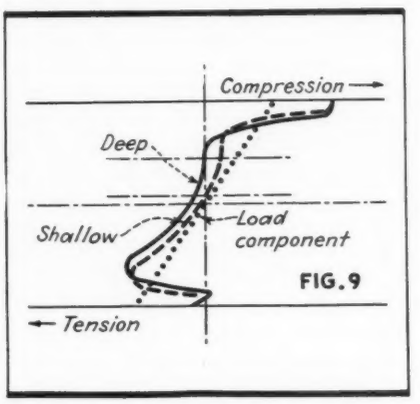


Fig. 9—Diagram showing influence of depth of pre-stressed layer

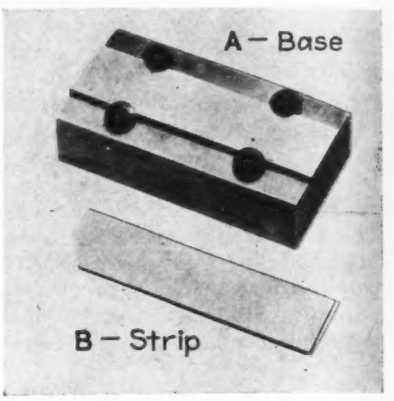


Fig. 10—Apparatus for measuring compression stressed layer

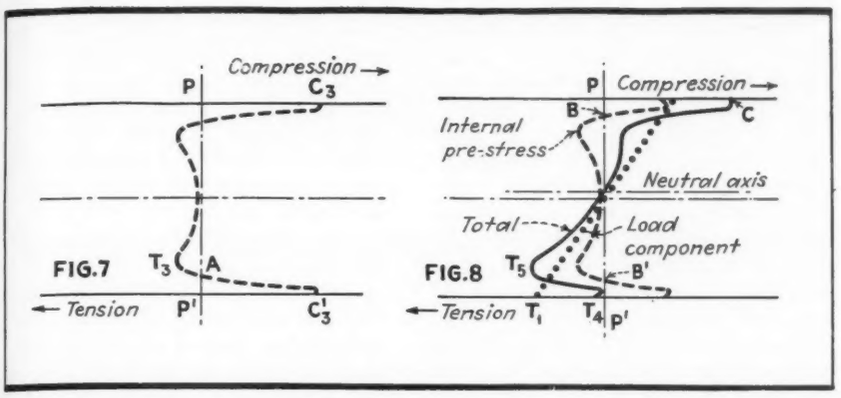


Fig. 7—Probable stress diagram for an unloaded beam with pre-stressed surfaces.
Fig. 8—Probable stress diagram of a loaded beam with pre-stressed surfaces

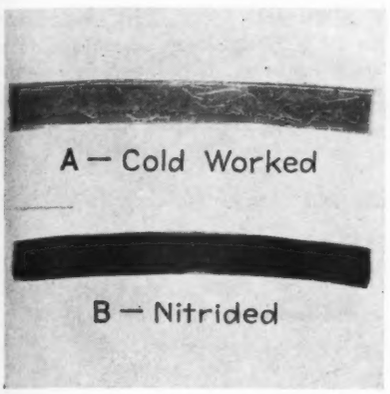


Fig. 11—Measuring strips after removal from heavy base block

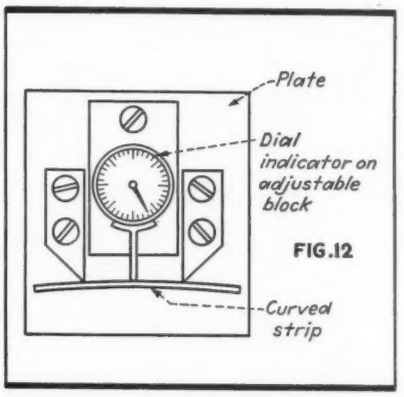


Fig. 12—Fixture and dial indicator for measuring curvature of strip

greater fatigue strength than the same material in the unclad state. A nitrided specimen is probably superior to other forms of hard cladding because, in addition to its higher physical properties, this thin layer is highly stressed in compression, therefore, it is less notch sensitive.

While on the subject of beneficial residual stresses, mention should be made of surface compressive stress obtainable by heat-treatment. By a rapid quench it is possible to trap compressive stress in the chilled surface and corresponding tension stress in the core, but this method, although showing some benefit in fatigue, is not so effective as the other methods that have been discussed.

Cold working increases the hardness of most metals including steel at least in the range of low hardness, and usually results in residual stresses of varying degrees and patterns. Cold working also alters other physical properties and sometimes fractures the material. With the known sensitivity of materials to fatigue, it is obvious that engineers must learn how to control cold work, just as they have had to learn how to control heat-treatment, in order that some benefit can be derived from the good effects and the evil effects overcome. No one would think of specifying a heat-treatment without stating whether the temperature should be raised or lowered and in which order and to what extent, yet that is the way in which cold work is now thought of. Cold working can be good or bad depending upon how it is done and for what purpose.

The magnitude of the sub-surface tension stress in a loaded beam having compression pre-stressed surfaces will vary with the amount of compression pre-stress and with the depth of the pre-stressed layer. Fig. 9 shows that the sub-surface tension stress may sometimes be greater for a deeply pre-stressed layer than for a layer of less depth. It would, therefore, seem important to control the compression stressed layer as to stress magnitude and depth with considerable accuracy by proper selection of the curvature of the rolling or peening instruments and by the pressure that is applied. (See *A.S.M.E. Trans.*, Vol. 57, 1935, "Effect of Surface Rolling on the Fatigue Strength of Steel," O. J. Horger).

A simple and practical apparatus for measuring compression stresses in a surface layer consists of attaching a thin flat strip *B* to a heavy base *A* as shown in Fig. 10, and then rolling or peening the strip with the same intensity that is given to the machine part. The strip when removed from the base will be found to be curved as shown at *A* in Fig. 11, with the convex surface on the cold worked side. The depth of the stressed layer can be determined from the curvature of the strip. In Fig. 12 is shown a method for measuring the curvature of the strip with an indicator.

The chart Fig. 13 records the stress magnitude and the depth of the stressed layer at constant cold work intensity of two such test strips. The cold worked surfaces of these strips, the Rockwell C hardness being respectively 64 and 40, were honed away in small increments and the curvature was measured after the removal of each thin layer. The changing curvature as metal was removed provided data from which the compressive stress in each layer could be calculated. Results are shown in the chart, Fig. 13. As would be expected, because of the higher yield point the harder specimen was found to be more highly stressed than the softer specimen. Fig. 13 also shows the surface compressive stress which resulted from nitriding another specimen. The procedure for this experiment was the same as for measuring the stress caused by peening except that the face of the specimen which was in contact wth the heavy base was plated in order to limit the nitriding to the outer face of the strip. On removal from the base after nitriding, the strip was curved convex on the nitrided side as shown at *B* in Fig. 11. It seems, therefore, that the well known resistance of nitrided specimens to fatigue, results primarily from the compressively stressed surface layer.

While the peened specimens, described in the preceding paragraph, were being honed it was found that the strips did not fully recover their original flat form. To determine if this residual curvature was caused by a "set" in the material or was the result of honing, other flat strips that had not been peened were honed. These strips developed the same curvature as the residual curvature in the peened specimens demonstrating that honing produces a compressively stressed layer. The approximate magnitude of this honing stress is also shown in the chart Fig. 13. Additional tests have shown that lapping also introduces surface compressive stress.

Carburized layers of parts are also

stressed in compression. Two opposite faces of the half-inch square specimen shown in Fig. 15 (*A*) were carburized while the other two faces were protected by copper plating. The specimen was quenched and tempered in the usual manner after which it was split with a saw as shown in Fig. 15 (*B*). Note that the parts are curved convex on the outer faces, thus indicating compressive stresses in their faces. In another carburized member, an analysis of the residual stresses by a method similar to that described for peened and nitrided strips, indicated the residual stress pattern shown in Fig. 14. It is interesting to note the magnitude of the compressive stress in the carburized layer and the reduced compressive stress, possibly even tension stress, in a thin surface layer. When carburized parts such as bearing races, wrist pins and gear teeth are ground the surface may be expected to be stressed in tension as is indicated by the dotted line in Fig. 14, and also by Fig. 2 which shows the magnitude of residual stresses in spring steel caused by grinding.

The residual compressive stress in a carburized layer may be a hazard for members stressed in tension, because the tension stress in the core is equal to the working load plus the tension load caused by the compressive preload of the case. For members stressed in bending and in torsion the residual compressive stress in the carburized case improves the fatigue strength of the part except for the thin surface layer which, especially after grinding, is severely stressed in tension. It is, as was indicated in Fig. 13, a simple matter to convert this thin tension stressed layer into stress in compression by suitable peening or rolling operations.

Gear steels and steels for many other parts have long been selected by false standards that are based only upon arbitrary laboratory tests, among which are fatigue tests of ideal specimens. For many years, industry has paid premium prices for alloy steels because of their fancied advantages when used in gears and in other parts. Fatigue tests on actual machine parts correlated with service records have shown that there is no detectable difference between the high priced alloy steels and many of the low priced alloy steels when used in many machine elements (See *A.S.T.M. Proceedings,* Vol. 35, Part 2, 1935, pp. 99-146, "Rear Axle Gears—Factors Which Influence Their Life," Almen and Boegehold). This is probably because machine parts are so far removed from the ideal laboratory fatigue specimens that the latter are misleading as measures of worth. This is indicated by the relative slopes of the fatigue curves (see *S.A.E. Journal,* Vol. 50, 1942, pp. 52-61, "Facts and Fallacies of Stress Determination," J. O. Almen) since the slopes of fatigue curves for machine parts are always steeper than the slopes of fatigue curves for the preferred laboratory specimens by which materials are usually selected.

From all of this it can be seen that the study of fatigue of materials is properly the joint duty of the metallurgical, engineering and production departments. Unless all of these departments have an understanding of fatigue phenomena, they cannot recognize their individual responsibilities. There is no definite line of demarcation between the mechanical and metallurgical factors that contribute to fatigue, therefore, there must be close cooperation between the metallurgist and the engineer. Until this is done, engineers cannot hope to make full use of available materials.

Fig. 15—Half-inch square specimen with top and bottom faces carburized and hardened

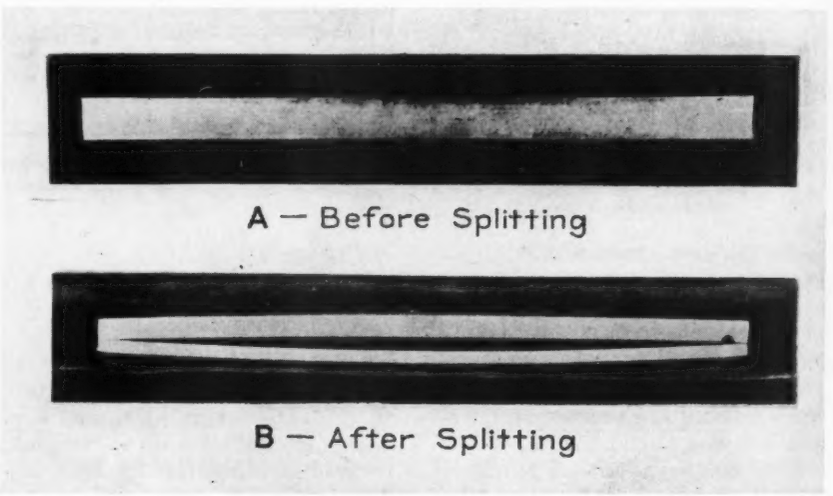
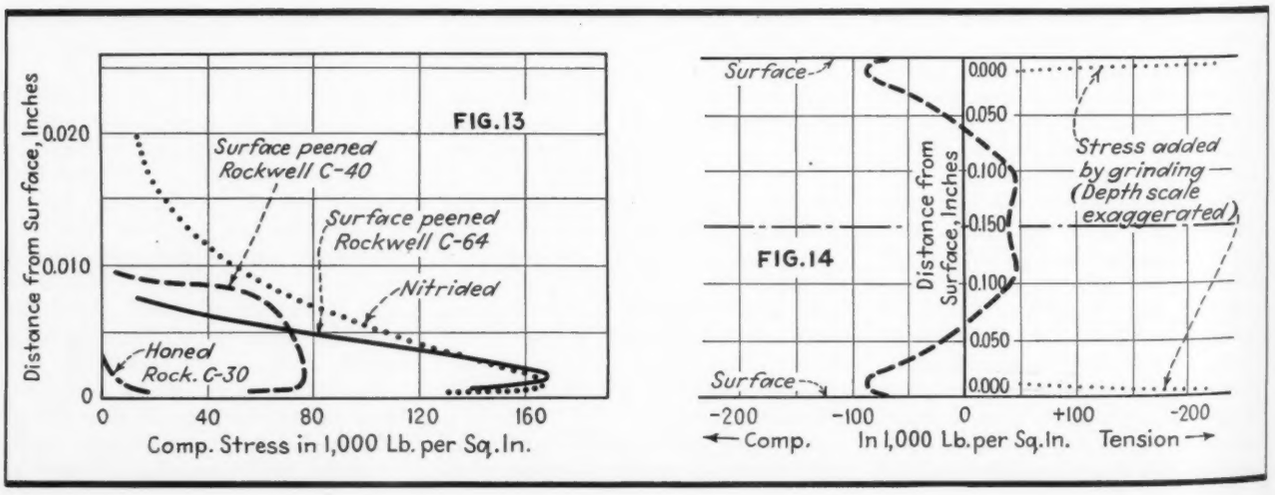
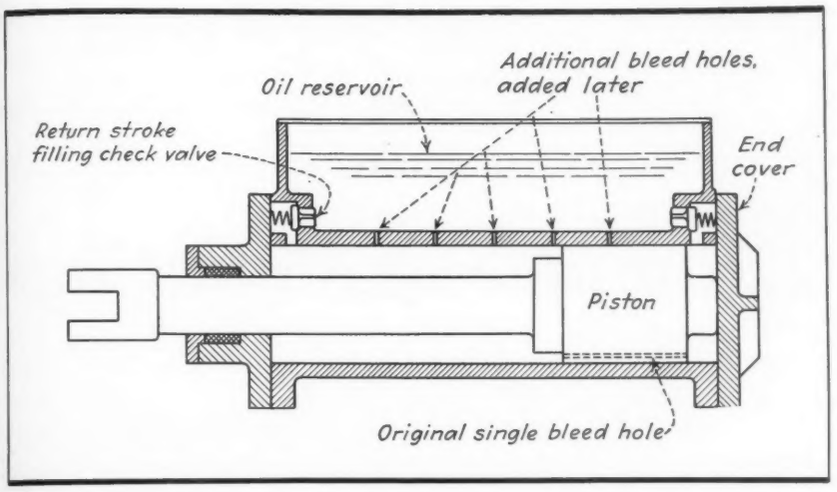


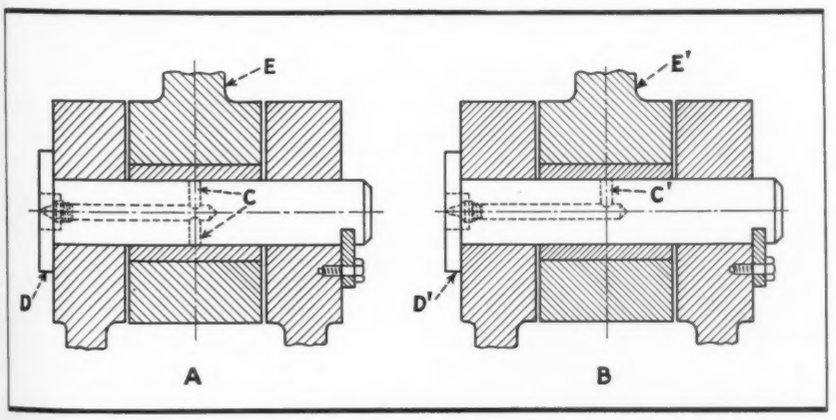
Fig. 13—Stress imposed by various surface treatments on test strips. Fig. 14—Residual stress pattern in steel strip after carburizing and hardening.



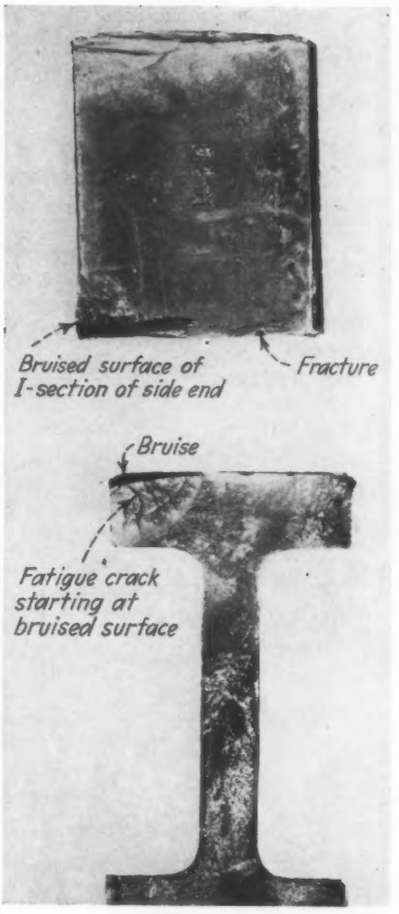
CAUSES AND CURES



Double-acting hydraulic shock absorber was designed and built to cushion a heavy reciprocating mass at each end of the stroke. First attempts using a single bleed hole in the piston caused violent deceleration, finally the end cover broke. Bleed hole in piston was enlarged, but the cushioning was still too violent. To relieve the pressure on the bleed side of the piston, holes were drilled through the cylinder wall at the bottom of the oil reservoir. The additional holes caused a slight cushioning at start of slowdown, that increased with the drop in speed as the piston covered each hole in turn. Result was a smooth action with practically uniform deceleration over the whole travel of the shock absorber.



Joint for a toggle, shown at *A*, consisted of a stationary pin *D* held in a forked casting by a keeper plate and a bronze bushing in the end of a swinging rod *E*. For lubrication, pin *D* had a grease hole with two outlets *C* drilled diametrically opposite each other. It was found that after the bushing had become worn to some extent that the grease lubricant would harden in the upper hole *C*, so that fresh grease would flow only through the bottom hole. To get grease into the upper half of bearing, where load is carried, a new pin *D*, shown at *B*, was made having only one grease outlet hole *C* to insure lubrication even if grease did harden at end of hole.



Fatigue cracks sometimes start at a bruised surface, which is somewhat coldworked and liable to crack. The illustration shows such an example. The fatigue crack extends across about half of the section before final fracture. Note how the fracture radiates out from the surface of the bruised surface of the section. This is a fluted side rod and must have been bruised crosswise affording ready starting lines for the fatigue cracks which followed in several places thus giving the fracture the frilled appearance. Bruises should be ground out lengthwise of the rod and left smooth. Cross grinding or filing is dangerous.

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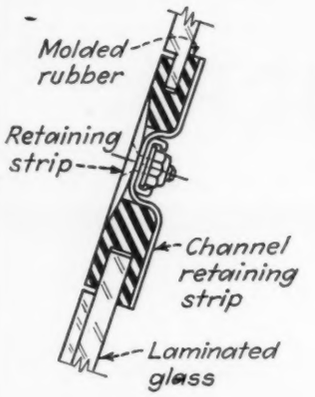
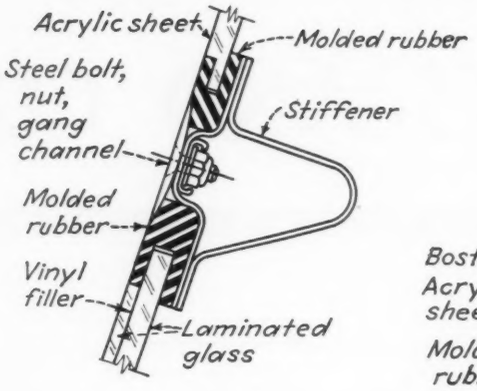
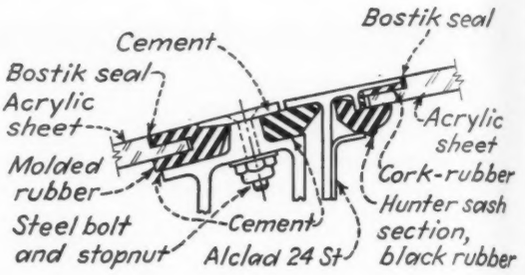
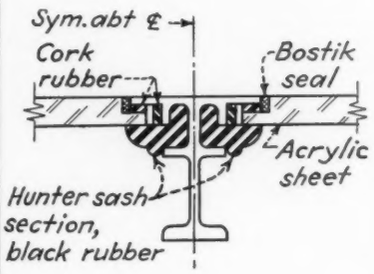
Examples of Mountings For Transparent Aircraft Inclosures

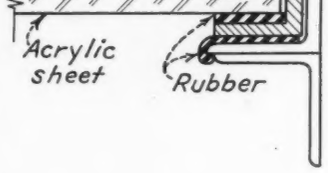


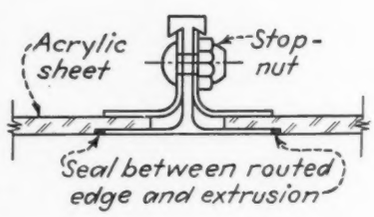


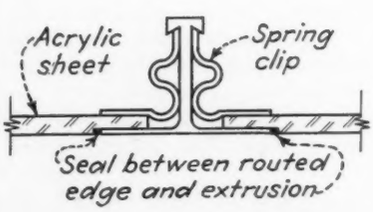
FLUSH MOUNTINGS

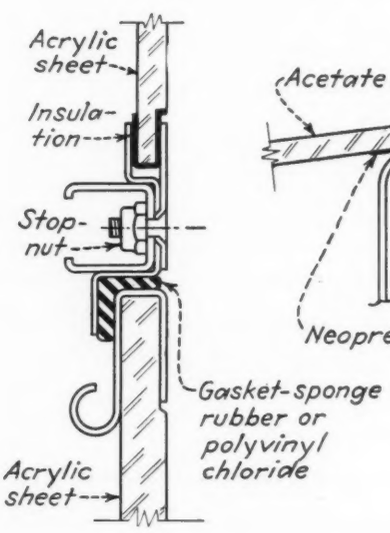


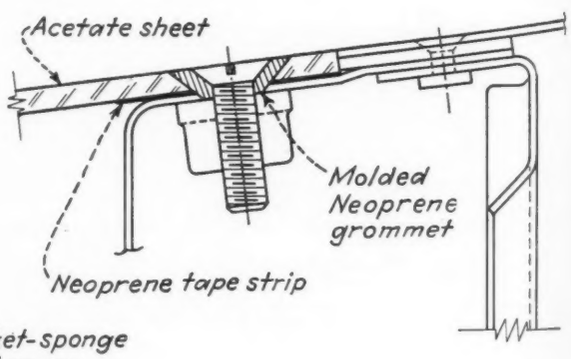


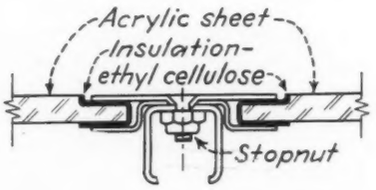


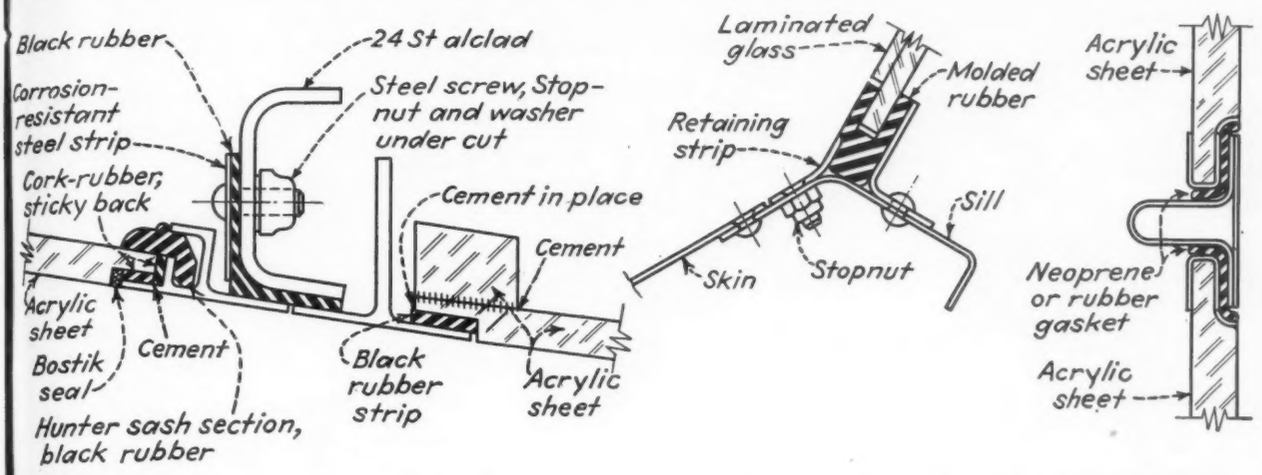


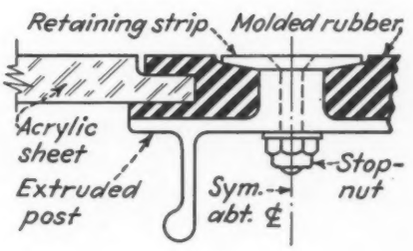












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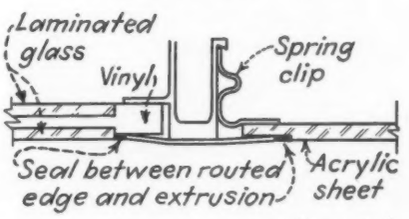
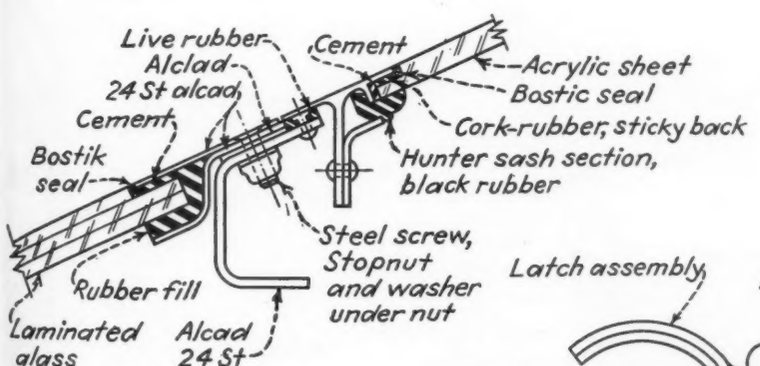
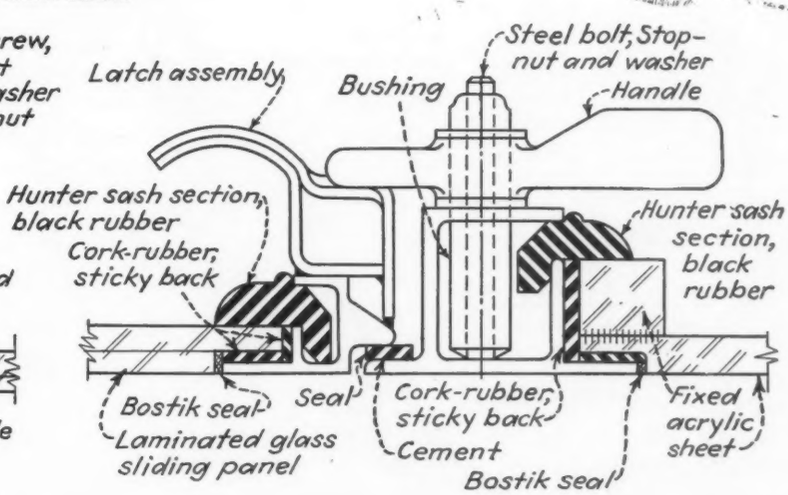
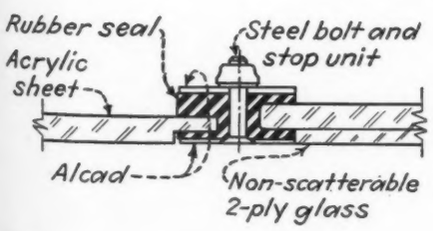
Details of typical mountings for transparent plastic inclosures for aircraft are presented in this follow-up of "Design Methods and Details for Transparent Aircraft Inclosures" published in PRODUCT ENGINEERING for May. Other companies beside Glenn L. Martin which contributed material for this section are North American Aviation, Inc., Vega Aircraft Corporation, Republic Aviation Corporation and Fairchild Engine & Aircraft Corporation.

ACRYLIC AND GLASS SHEET CONNECTIONS

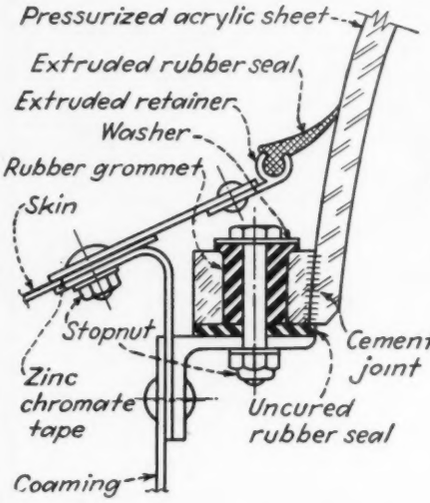


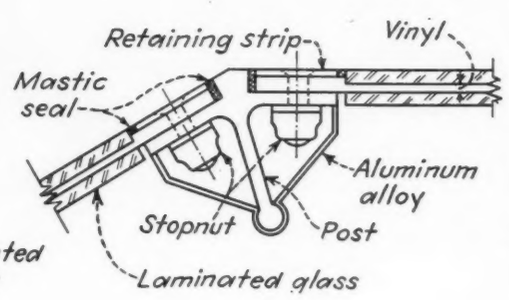


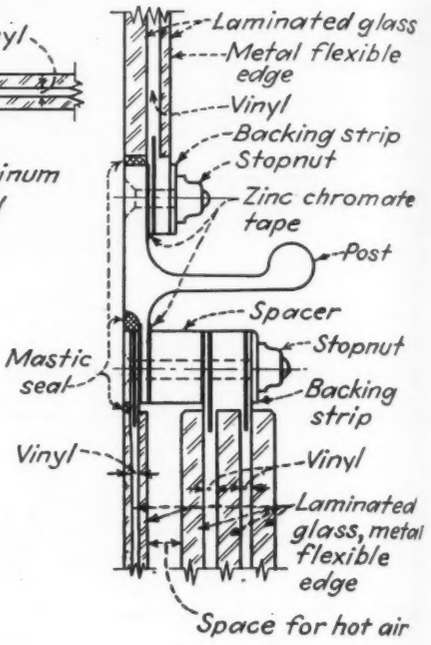




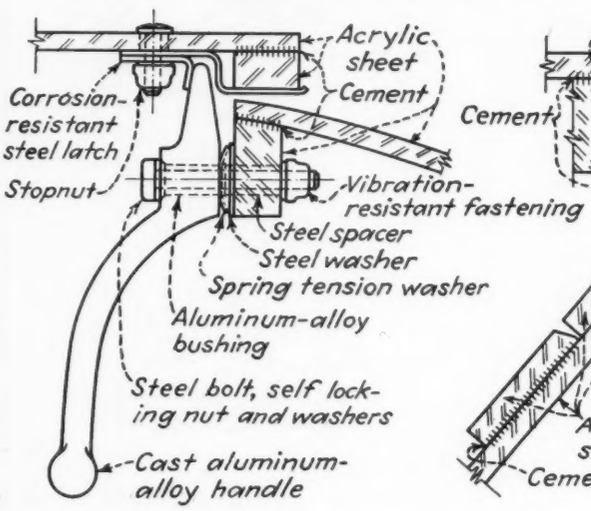
MOUNTINGS FOR PRESSURIZED INCLOSURES

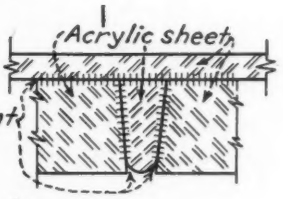


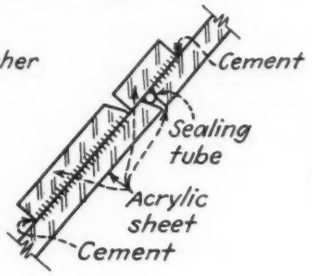


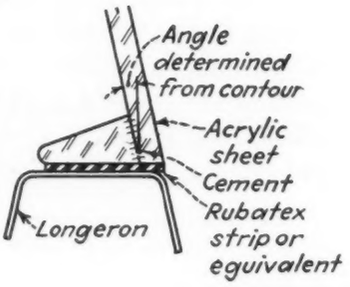


CEMENTED JOINTS

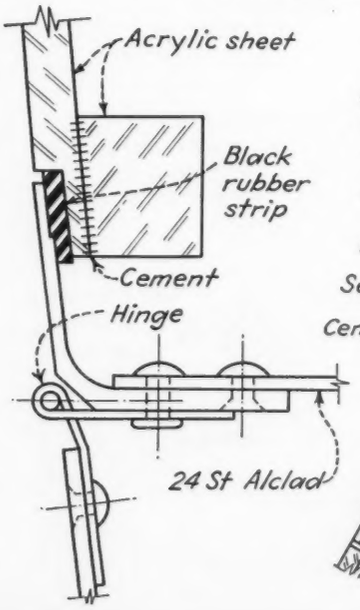


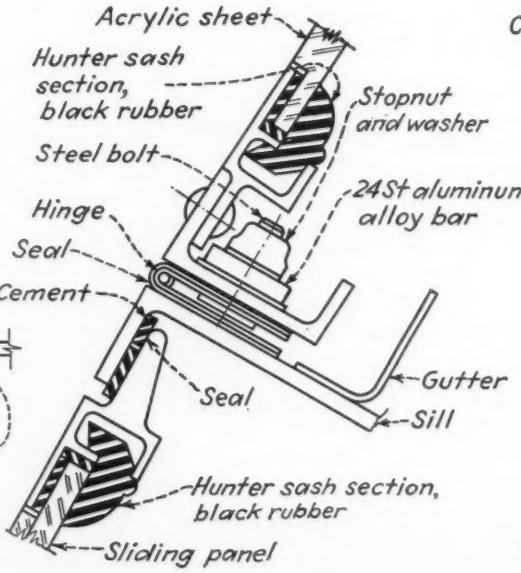


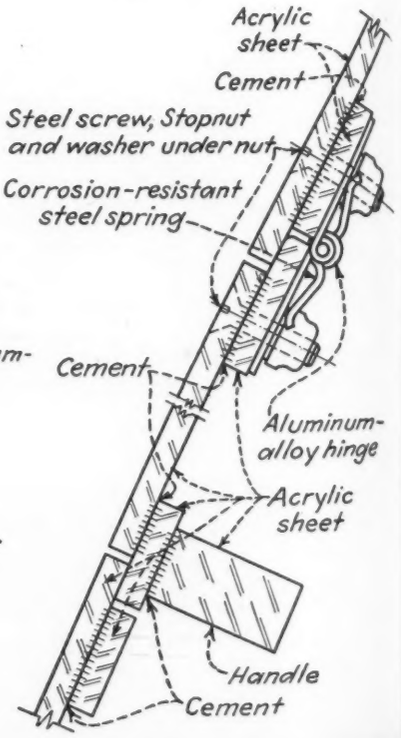


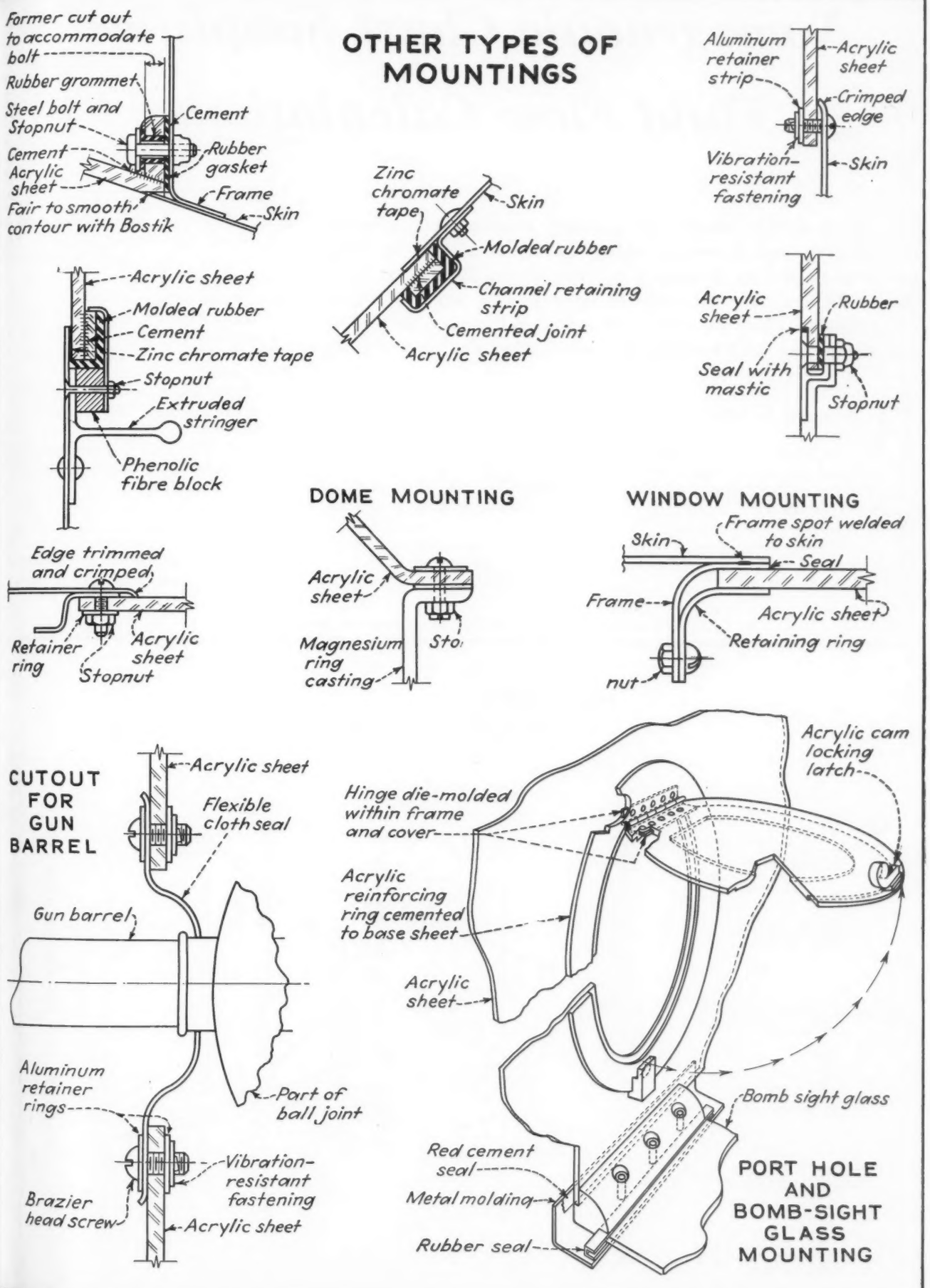


HINGED JOINTS








OTHER TYPES OF MOUNTINGS
Former cut out to accommodate bolt
Rubber grommet
Steel bolt and Stopnut
Cement
Cement
Acrylic sheet
Rubber gasket
Frame
Fair to smooth contour with Bostik
Skin
Zinc chromate tape
Skin
Molded rubber
Channel retaining strip
Cemented joint
Acrylic sheet
Aluminum retainer strip
Acrylic sheet
Crimped edge
Vibration-resistant fastening
Skin
Acrylic sheet
Molded rubber
Cement
Zinc chromate tape
Stopnut
Extruded stringer
Phenolic fibre block
Acrylic sheet
Rubber
Seal with mastic
Stopnut
Edge trimmed and crimped
Retainer ring
Acrylic sheet
Stopnut
DOME MOUNTING
Acrylic sheet
Magnesium ring casting
WINDOW MOUNTING
Skin
Frame spot welded to skin
Seal
Frame
Acrylic sheet
Retaining ring
nut
CUTOUT FOR GUN BARREL
Acrylic sheet
Flexible cloth seal
Gun barrel
Aluminum retainer rings
Part of ball joint
Vibration-resistant fastening
Brazier head screw
Acrylic sheet
Hinge die-molded within frame and cover
Acrylic reinforcing ring cemented to base sheet
Acrylic sheet
Acrylic cam locking latch
Bomb sight glass
Red cement seal
Metal molding
Rubber seal
PORT HOLE AND BOMB-SIGHT GLASS MOUNTING

Nomographic Chart Simplifies Fluid Flow Calculations

Long mathematical calculations normally necessary to find pressure drop through hydraulic tubing, may be eliminated by using this alignment-chart developed by The Glenn L. Martin Company. The chart can be used for three specific types of oils—Army 3580-C-M between +170 and −40 deg. F.; Army 3580-C-L; and Army-Navy AN-VV-0-366a between +170 and −70 deg. F.

BY completing the following steps in order, the pressure drop P can be found, when the knowns are the kind of fluid, temperature, tube diameter D, and flow of fluid G. Viscosity V for an oil is found opposite the temperature under study.

1. On viscosity-temperature chart for the kind of fluid used, establish point 1 on scale V.

2. From specific gravity-temperature chart for the fluid, find specific gravity S and locate point 2 on scale S. Connect points 1 and 2, which locates point 3 on scale U.

3. For point 4, connect 3 with the known flow value on scale G.

4. Connect 2 with known tube diameter D on scale D to get point 5.

5. Where line connecting 3 and 4 crosses scale $T.S._1$, point 6 is located.

6. Where line connecting 2 and 5 crosses scale $T.S._2$, point 7 is located. Draw line connecting 6 and 7, and where it crosses K, 8 is fixed.

7. Using criterion number 8, find friction factor 9 on KF conversion chart. This value is located on scale F for point 9.

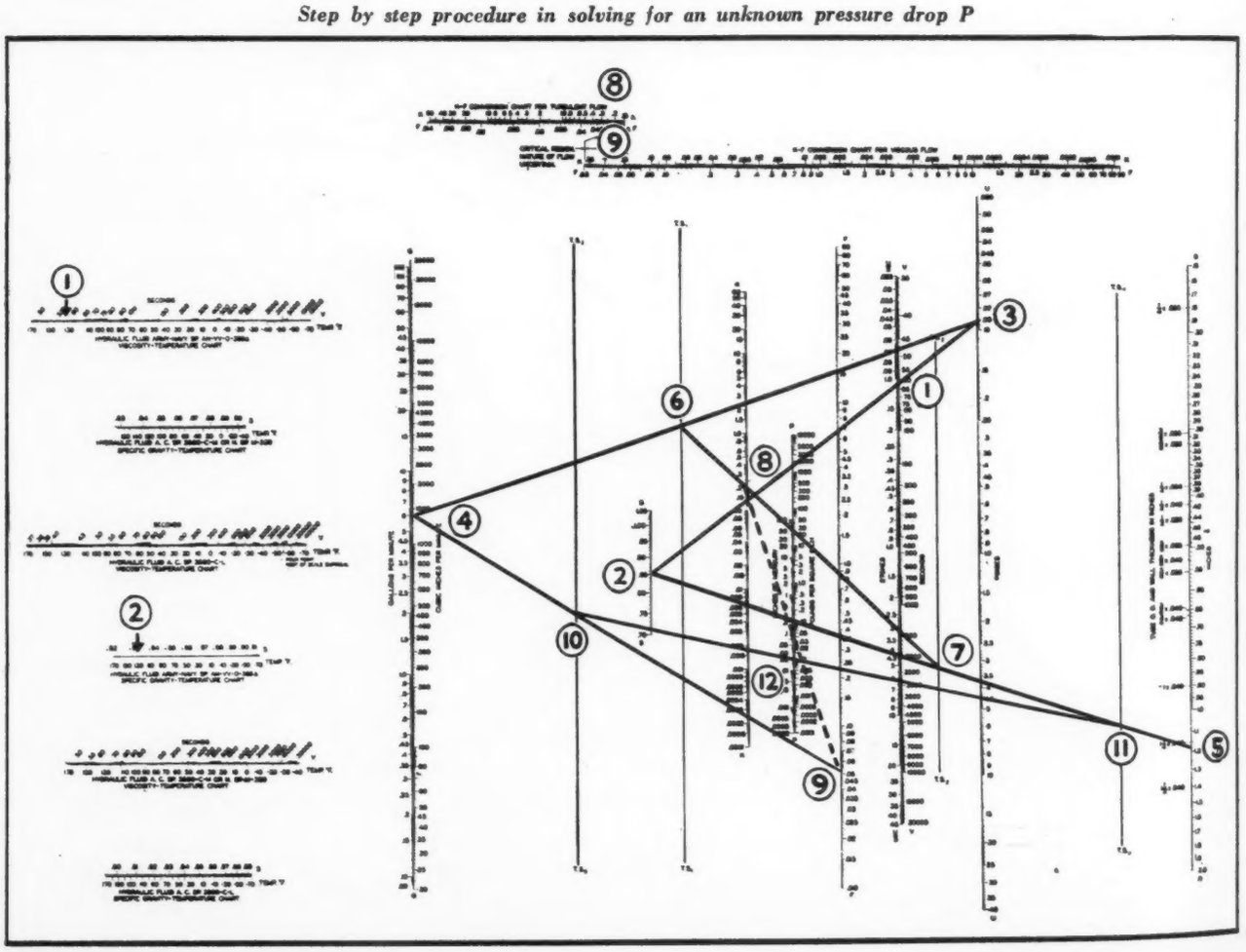
8. Draw line connecting 4 and 9, and where it crosses $T.S._3$, point 10 is located.

9. Point where line 2-5 crosses scale $T.S._4$ is point 11. Connect points 10 and 11.

10. Where line 10-11 crosses scale P, the unknown pressure drop 12 is found.

The nomographic chart is presented on the folded page.

Step by step procedure in solving for an unknown pressure drop P



ALIGNMENT CHART FOR DETERMINING FLOW CHARACTERISTICS OF H

D = INSIDE DIAMETER OF TUBE
F = FRICTION FACTOR
G = FLOW OF FLUID
K = CRITERION NUMBER
P = PRESSURE DROP PER FOOT OF TUBE

S = SPECIFIC GRAVITY
U = ABSOLUTE VISCOSITY
$\frac{U}{S}$ = KINEMATIC VISCOSITY
V = SAYBOLT UNIVERSAL VISCOSITY
T.S. INDICATES TURNING SCALE

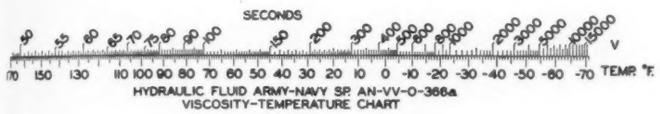
THE CHART IS FOR THE SOLUTION OF THE EQUATIONS:-

$$\frac{U}{S} = .0022V - \frac{1.80}{V} \qquad K = \frac{.406GS}{100UD} \qquad P = \frac{.0134FSG^2}{D^5}$$

UIVALENT LENGTHS OF COMMON BENDS AND FITTINGS
PRESSED IN DIAMETERS OF THE TUBE.

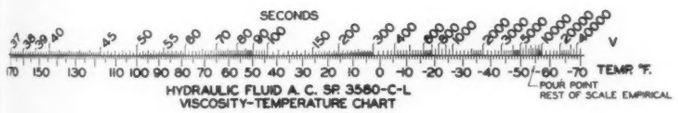
0° BENDS, CENTER-LINE RADIUS OF 2 TO 8 DIAMETERS	10
0° BENDS, LARGE RADIUS	0
0° ELBOWS, CORED	30
90° ELBOWS, DRILLED	50
TEES, FULL SIZE BRANCH	60
OBTUSE ANGLE BENDS (A=DEFLECTION FROM TUBE IN DEGREES)	$10\left(\frac{A}{90}\right)^2$
OBTUSE ANGLE ELBOWS (A=DEFLECTION FROM TUBE IN DEGREES)	$50\left(\frac{A}{90}\right)^2$

PE OF FLOW: To determine whether flow will be turbulent or viscous, ve for "K" as shown on the chart and find whether it falls on the tur-lent or viscous K-F conversion scale.

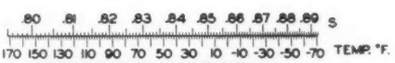


HYDRAULIC FLUID ARMY-NAVY SP. AN-VV-O-366a
VISCOSITY-TEMPERATURE CHART

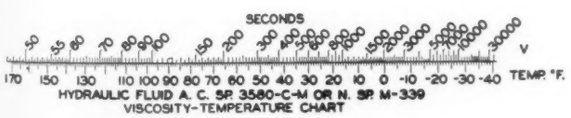
HYDAULIC FLUID ARMY-NAVY SP. AN-VV-O-366a
SPECIFIC GRAVITY-TEMPERATURE CHART



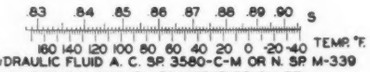
HYDRAULIC FLUID A. C. SP. 3580-C-L
VISCOSITY-TEMPERATURE CHART



HYDRAULIC FLUID A. C. SP. 3580-C-L
SPECIFIC GRAVITY-TEMPERATURE CHART



HYDRAULIC FLUID A. C. SP. 3580-C-M OR N. SP. M-339
VISCOSITY-TEMPERATURE CHART



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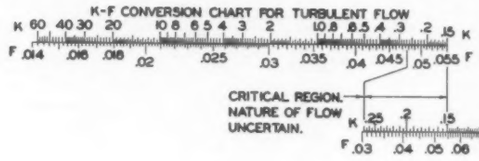
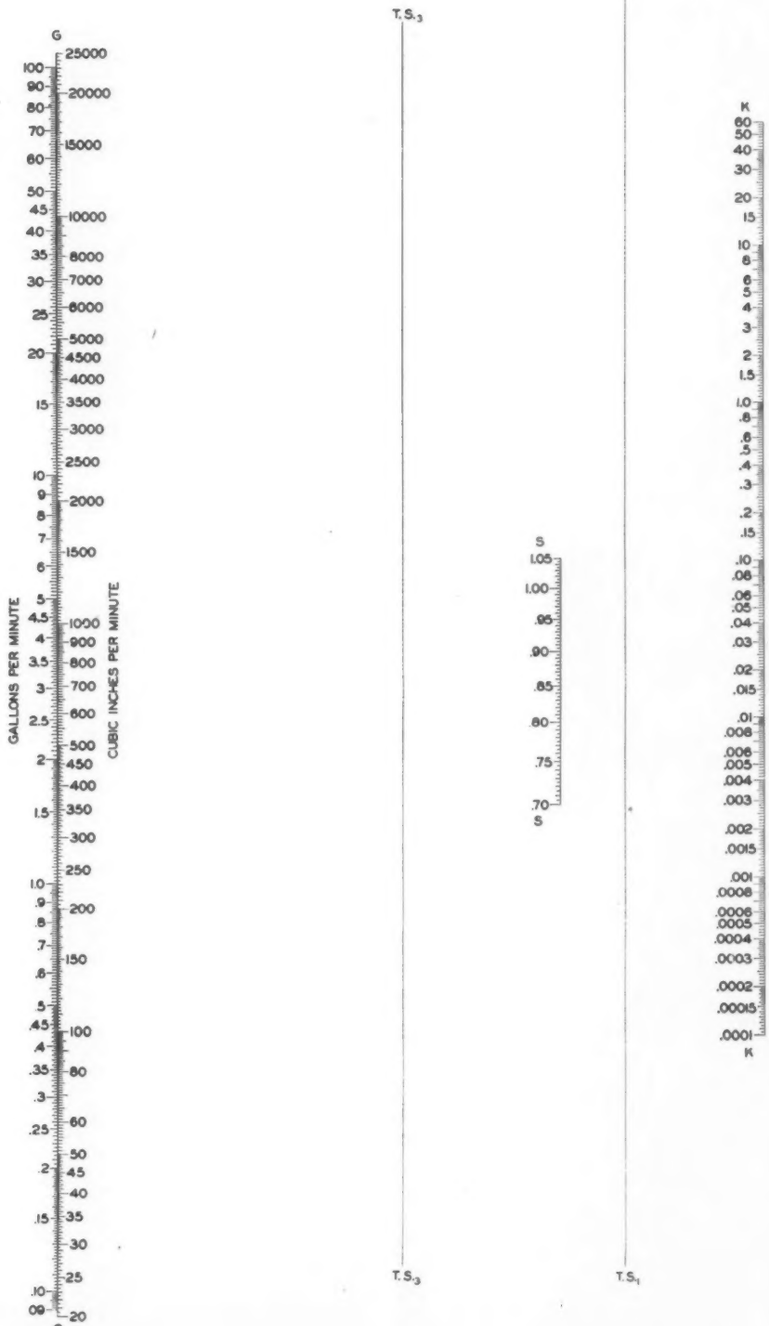
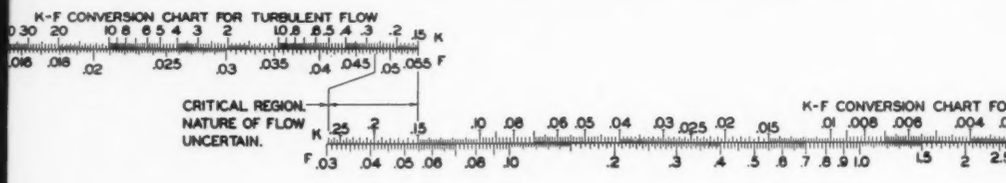
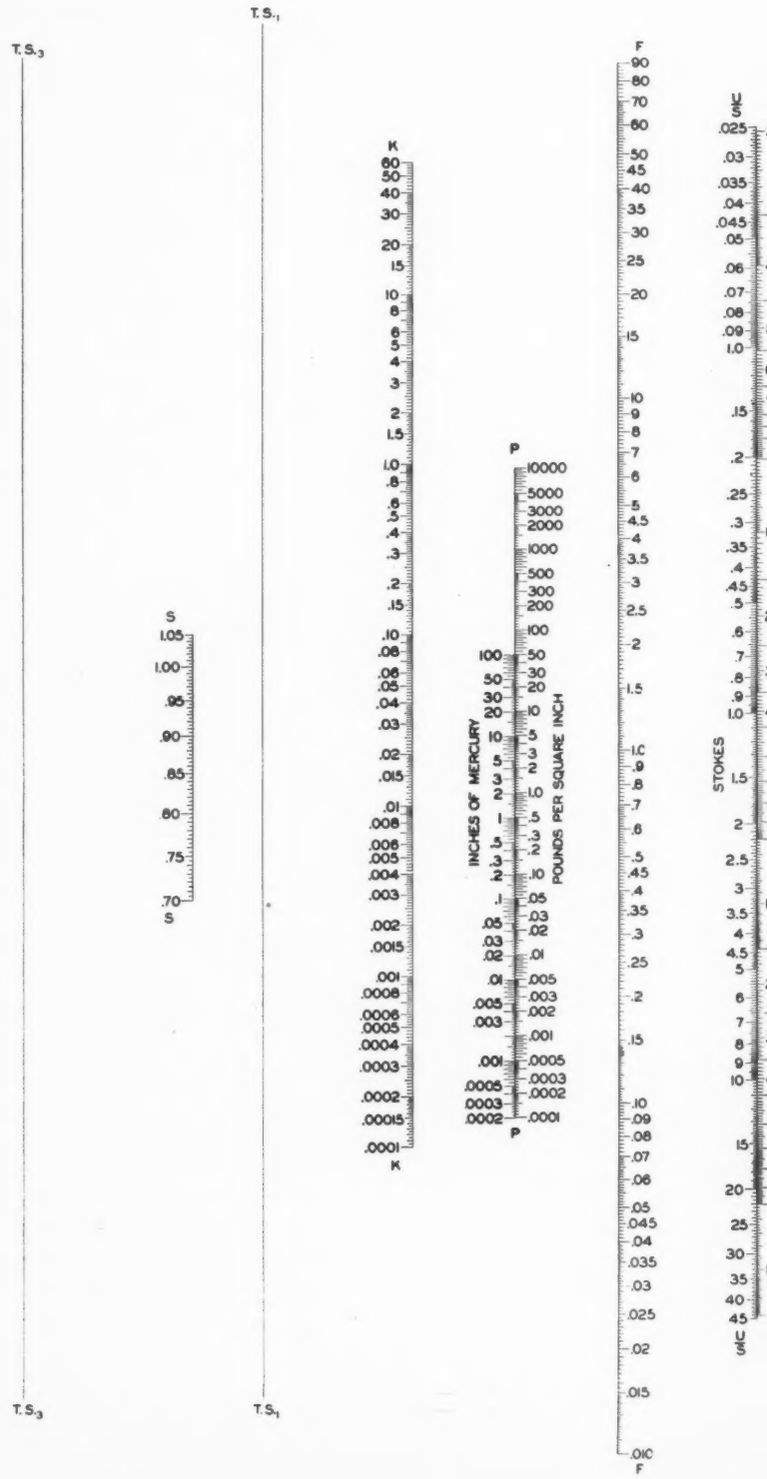
SPECIFIC GRAVITY-TEMPERATURE CHART



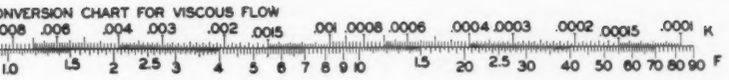


OR DETERMINING FLOW CHARACTERISTICS OF HYDRAULIC FLUID IN





C FLUID IN TUBES



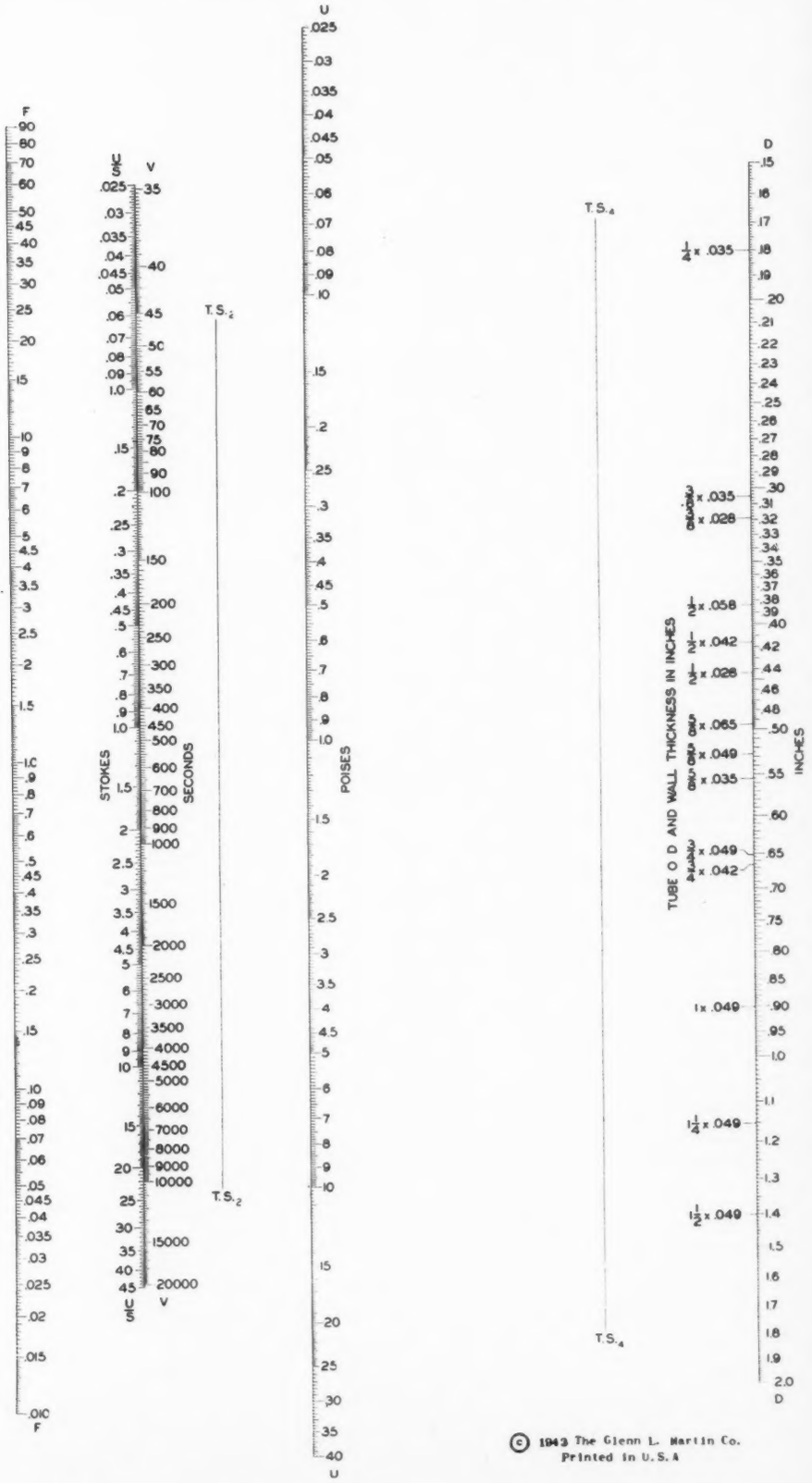


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Fig. 7—Pouring a large magnesium alloy sand casting

Magnesium Properties As They Affect Design

Continuing the considerations of various physical properties of magnesium alloys as they affect the design of structural members, the second article of this series deals with strength of magnesium alloys in bending, hardness and wearing properties, resilience and toughness, and their resistance to fatigue. This series of articles, arranged from material prepared by American Magnesium Corporation, is to be expanded in book form.

TYPICAL values of modulus of elasticity are given for various materials in Table IV. Since, with identical cross-sections, the stiffness of a structural member is governed by modulus of elasticity, the low modulus of magnesium must be taken into account when rigidity or stability is a factor. In castings this characteristic is often of no importance because, for foundry reasons, the wall thicknesses are usually heavier and the casting is, therefore, more resistant to elastic deflection than required. Where stiffness is lacking in portions of a casting it may usually be obtained by local increases in metal section, ribs, corrugations or other measures, with only slight increase in weight. Similar conditions sometimes apply to forgings and extrusions where manufacturing limitations may dictate heavier sections than would be required for stiffness.

Where, however, structural rigidity is the controlling factor, an increase in section depth is the most efficient way of increasing stiffness in order to compensate for low modulus of elasticity, since stiffness in bending is proportional to modulus of elasticity and to moment of inertia of the section. As an illustration of the relationship between thickness, weight and stiffness of sheet or plate made of magnesium as compared to sheet or plate made from aluminum or steel, assume that a strip of metal is loaded as a simple beam or as a cantilever beam and that the deflection of the center of the simple beam or the end

Table IV—Comparative Properties of Structural Materials

Material	Alloy	Brinell hardness [a]	Approximate relative toughness per unit volume [b]	Approximate relative toughness per unit weight [b]	Endurance limit [c] lb. per sq. in.	Relative endurance limit based on equal weight [d]	Typical shear strength lb. per sq. in. [e]	Modulus of elasticity lb. per sq. in.	Torsional modulus of rigidity lb. per sq. in.
Magnesium...	Cast AM265-C	48	41	41	11,000	87	18,000		
"	" AM260-T4	..	100 [s]	100	12,500	100	20,000		
"	" AM260-T6	78	29	29	11,500	91	22,000		
"	" AM240-T4	52	..	..	11,000	89	20,000		
"	Wrought AM3S	40	72	75	11,000	91	16,700	6,500,000 [s]	2,400,000
"	" AM-C52S	..	174	178	15,000	122	19,000		
"	" AM-C57S	55	158	160	17,000	138	20,500		
"	" AM59S	70	118	118	18,000	144	22,000		
"	Die-Cast AM263	..	...	...	14,000	112	.....		
Aluminum....	Cast 43	40	29	20	6,500	36	14,000		
"	" 195-T6	80	46	30	6,500	34	30,000		
"	" 356-T6	70	33	23	8,000	44	27,000		
"	" 220-T4	75	161	115	7,000	40	33,000		
"	Wrought 3S-½H	40	86	56	9,000	48	14,000	10,300,000 [t]	3,850,000
"	" 52S-½H	67	133	91	19,000	104	21,000		
"	" 24S-T	105	384	262	18,000	95	41,000		
"	Die-Cast 13	...	...	...	15,000	83	.....		
Gray Cast Iron.....		200 [f]	4	1	15,000 [k]	30	44,000	15,000,000 [u]	6,000,000
Malleable Iron.....		130	322	80	26,000	52	48,000	25,000,000	10,700,000 [v]
Cast Carbon Steel.....		230 [g]	462	106	33,000	61	60,000	29,900,000 [w]	11,200,000
Structural Steel.....		150	462	107	33,000 [l]	61	45,000	28,000,000	10,000,000
Alloy Steel.....		280	577	132	83,000 [m]	155	110,000	29,000,000 [x]	11,000,000
High Brass, soft.....		52	577	124	12,000 [n]	21	33,000	15,000,000	5,640,000 [y]
High Brass, hard.....		153	134	29	16,500	28	43,000		
Die-Cast Zinc.....		75	...	...	.....	..	31,000		
Hard Maple.....		...	4	11	.....	..	1,500 [p]	1,600,000 [z]	[aa]
Phenolic Sheet.....		32 [h]	5 [i]	7	6,000 [r]	65	10,000 [q]	1,000,000 [bb]	

(a) Determined with 500 kg. load, 10 mm. ball for magnesium, aluminum and phenolic sheet. Others dependent upon sources.
(b) Capacity for energy absorption in plastic range of identical structural members stressed in tension or bending. All values are based on tensile properties and weights shown in Table III, May *P.E.* Relative toughness on equal weight basis was obtained by dividing relative toughness on equal volume basis by specific gravity and assuming AM260-T4 magnesium alloy as 100
(c) Reversed bending, R.R. Moore type machine. Based on 500,000,000 cycles for magnesium and aluminum. Bases for others depends on sources.
(d) Obtained by dividing endurance limit by specific gravity and assuming AM260-T4 magnesium alloy as 100.
(e) Single shear values obtained from double-shear tests for magnesium and aluminum alloys. Other values taken from various sources.
(f) Approximate.
(g) Cast medium-carbon steel varies between 130 and 325.
(h) Varies between 24 and 40.
(i) Actual energy absorbed is 3,900 in. lb. per cu. in.
(j) For oak a value of 13 in. lb. per cu. in. is reported.
(k) Assumed as 50 percent of tensile strength.
(l) 0.37 percent carbon, normalized.
(m) Assumed as 55 percent of tensile strength (150,000 lb. per sq. in.)
(n) Varies between 10,000 and 15,000 lb. per sq. in.
(p) Parallel to grain. 6,350 across grain.
(q) Varies between 5,000 and 11,000 lb. per sq. in. depending upon direction of laminations.
(r) Reported value for fabric base phenolic sheet is 60 to 65 per cent of static strength.
(s) Modulus of AM3S type alloys has been reported as somewhat lower than 6,500,000 lb. per sq. in. A value of 5,500,000 lb. per sq. in. is given by Bureau of Standards Research Paper RP-1347.
(t) Modulus of aluminum alloys with high silicon content, like No. 13 alloy, is about 11,000,000 lb. per sq. in.
(u) Varies between 12,000,000 and 18,000,000 lb. per sq. in.
(v) Based on Poisson's ratio 0.17.
(w) 0.33 C, 0.72 Mn.
(x) Modulus of 18–8 stainless steel is 26,000,000 lb. per sq. in.
(y) Based on Poisson's ratio 0.33.
(z) Modulus of timber in bending varies between 1,000,000 and 2,200,000 lb. per sq. in.
(aa) See ANC-5, p. 2–8.
(bb) Initial modulus values for reinforced plastics have been quoted by different investigators as ranging from 350,000 or less to well over 2,000,000 lb. per sq. in. depending on fabricating conditions, type of base and filler, and direction of lamination.

of the cantilever beam is the only criterion that is applied. It is then possible to express the deflection as

$$\Delta = \frac{K_1 P}{EI} = \frac{12 K_1 P}{EBH^3}$$

where

Δ = elastic deflection under load, inches
K_1 = factor based on conditions of loading and support, and span length of member
P = load, lb.
E = modulus of elasticity, lb. per sq. in.
I = moment of inertia
B = width of rectangular member, in.
H = depth of rectangular member, in.

For constant width, the deflection then becomes

$$\Delta = \frac{K_2}{EH^3}$$

where

K_2 = factor based on width, loading, support, and span length of member.

Relative weights or relative stiffnesses for sheet of various thicknesses can be computed from this equation. Such a comparison is made in Table V. The values given in this table are based on equal thickness, equal stiffness and equal weight respectively. Although they apply to idealized cases, they do show limiting possibilities of magnesium sheet.

Other properties and conditions that are influenced by low modulus of

elasticity of magnesium are vibration, resilience, column strength, collapsing strength of tubing, stresses caused by thermal expansion, acoustic properties, straightening characteristics, springback in forming, and deflection in machining. Proper design and shop practice can help avoid disadvantages and make use of advantages resulting from low modulus of elasticity.

The modulus of elasticity in shear, or modulus of rigidity, is about 2,400,000 lb. per sq. in. for magnesium and its commercial alloys, corresponding to a value of about 0.34 for Poisson's ratio. Table IV gives shear moduli of some other structural metals.

Compressive Properties

1. Compressive Strength. Typical compressive properties of structural materials were given in Table III, p. 280, May P.E. Yield strength in compression of magnesium castings is about equal to yield strength in tension, whereas in most wrought magnesium alloys it is considerably lower. This difference is important in designing members that depend on yield strength in compression, such as short columns and compression flanges of beams.

Yield strength of most wrought magnesium alloys in compression is about 60 to 70 percent of the yield strength in tension, except for AM3S alloy as extruded, for which the value is only 37 percent.

2. Column Strength. The strength of long columns depends largely on modulus of elasticity, and that of short columns largely on compressive yield strength. Tests indicate that the following formula applies with a good degree of accuracy to column strength of AM57S magnesium alloy:

$$\frac{P}{A} = \frac{48{,}000}{1 + 0.00075\left(\frac{KL^2}{r}\right)}$$

with a maximum value equal to 95 percent of the compressive yield strength of the material, where

P = ultimate column load. lb.
A = cross sectional area, sq. in.
L/r = slenderness ratio
K = constant depending on end conditions of member: 0.5 for fixed ends, 1.0 for round ends.

The column curve in Fig. 8 was plotted from test data on AM57S alloy extruded angle. This material has a relatively low compressive yield strength. In the range of effective slenderness ratios from 0 to 60, compressive yield strength is more important than modulus of elasticity in influencing column strength, whereas for effective slenderness ratios greater than 60, modulus of elasticity is more important. Available test data indicate that for the usual structural magnesium alloys, compressive yield strengths vary from 11,000 to 27,000 lb. per sq. in., depending upon the alloy, heat-treatment, cross-section, and method of fabrication. For effective slenderness ratios greater than about 80 the curve shown for AM57S may be considered as applicable to all of these alloys. For ratios less than about 80 the column curves have not been completely defined.

3. Bearing Strength. Bearing strength of magnesium alloys is important in bosses supporting screw heads or nuts and in riveted or threaded joints. The ultimate bearing strength of magnesium alloy sheet may be taken as approximately 1.6 times tensile strength, a value slightly lower than that applying to aluminum sheet alloys (1.8). The value of 1.6 is based on an edge distance, in the direction of stressing, of not less than twice, and a sheet thickness of not less than one-fourth the diameter of the hole. Typical ratios of ultimate bearing strength and bearing yield strength to tensile strength, as tentatively determined on various magnesium sheet alloys and under various conditions, are given in Table VI. Similar ratios probably apply to most magnesium extrusion and casting alloys. The bearing yield strength was arbitrarily determined as the stress corresponding to an offset of 2 percent of the hole diameter from the initial straight-line of the bearing stress-hole elongation curve.

Bearing strength of magnesium alloys is closely related to their hardness. Examples of measures taken to obtain adequate bearing strength in magnesium designs will follow in the discussion of hardness and wear resistance and of joining methods.

Strength in Bending

1. Elastic Strength in Bending. For structural members and machine parts, strength in bending in the allow-

Table V—Relative Stiffness and Weight of Rectangular Magnesium, Aluminum and Steel Beams of Varying Thickness and Equal Width

(H = relative depth of beam in plane of bending)

Metal	H	H^3	Relative Weight	Relative Stiffness in Bending
Aluminum	1.00	1.00	100	100
Magnesium	1.00	1.00	65	63
"	1.17	1.58	76	100
"	1.53	3.58	100	226
Alloy Steel	1.00	1.00	100	100
Magnesium	1.00	1.00	23	22
"	1.65	4.46	38	100
"	4.36	82.88	100	1,857

Fig. 8—Column strength of AM57S alloy extruded angle 2½x2½x¼ in.

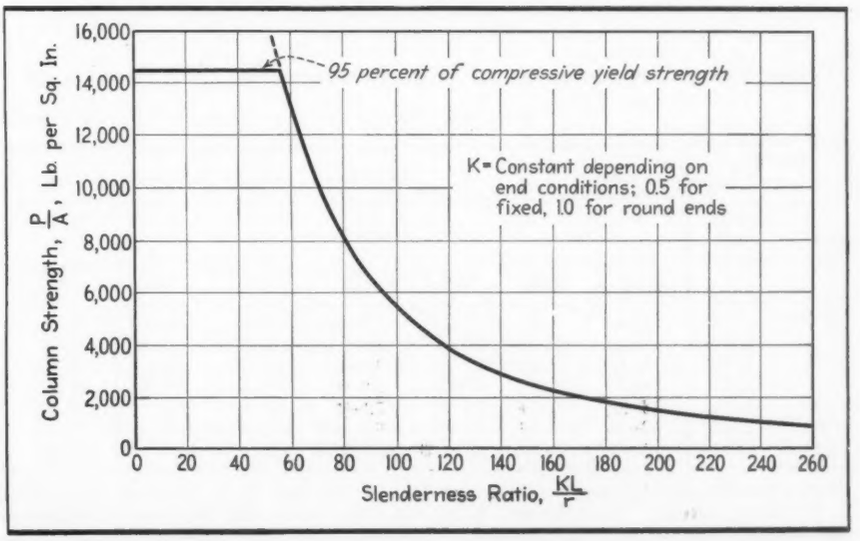

Table VI — Approximate Ratios of Bearing Strength to Tensile Strength of Magnesium Alloy Sheet (1)

Temper of Magnesium Sheet	Ratio of Bearing Yield Strength to Tensile Strength	Ratio of Ultimate Bearing Strength to Tensile Strength		
		$D/t = 8$	$D/t = 4$ or less	
			$E/D = 1.5$	$E/D = 2$ or more
Annealed (O).....	0.9	1.3	1.4	1.6
Hot rolled (R).....	1.0	1.3	1.4	1.6
Hard rolled (H).....	1.1	1.3	1.5	1.6

Notes: (1) Determined on AM3S, AM52S and AM-C57S alloy.
D = Pin Diameter
t = Sheet Thickness
E = Edge Distance (from center of hole)

able elastic range is proportional to permissible design stress and to section modulus of the stressed member. The section modulus of sheet is proportional to thickness squared, and its weight is proportional to specific gravity times thickness. In view of these facts, magnesium sheets may often be made both lighter and stronger than heavier metal sheets on which the allowable design stresses are higher.

2. Ultimate Strength in Bending. Although tensile strength is the generally accepted criterion for strength of a material, it does not always adequately indicate the strength under the more complex conditions of loading encountered in service. When structural members and machine parts are subjected to bending far beyond the elastic range of the material, the maximum moment cannot be predicted with ordinary analyses.

In order to obtain some indication of the maximum bending moment that a member will resist before fracture or buckling, the concept of "modulus of failure" was devised. This value, expressed in lb. per sq.in., is comparable to stress and is obtained when the maximum or failing moment of a member is substituted for bending moment in the ordinary flexure formula. The modulus of failure, S_u, then may be expressed as

$$S_u = M_{max.} \frac{c}{I}$$

where

$M_{max.}$ = failing moment of member, in. lb.
c = distance from neutral axis to most remote extreme fibre, inches
I = moment of inertia of cross-section of member

The modulus of failure of magnesium cast and wrought alloys as determined on ¾-in. diameter bars was shown to be about 1.8 to 2 times ultimate tensile strength. Because of low modulus of elasticity and the shape of the stress-strain curve for magnesium alloys, the modulus of failure for other shapes would be expected to be much less than these values.

For heavy I-beam and channel sections, the modulus of failure would be expected to be no greater than the tensile strength. For thinner sections local instability may cause failure before the yield strength of the member is developed. In such instances yielding in compression is much more significant in affecting stability than is yielding in tension. Actually, however, yield strength in bending of rectangular magnesium members compares favorably with yield strength in compression and approaches the yield strength in tension. This was reported by A. W. Winston in Paper 1979, *A.S.C.E. Transactions*, 1937, p. 1389.

For very thin webs or flanges, buckling may take place at stresses within the elastic range. Such buckling, however, is usually treated as a special case and is not considered as simple bending for which moduli of failure must be used.

Hardness and Wear Resistance

Typical hardness values are given in Table IV. AM246-T6 alloy, with a Brinell value of 85, has the greatest hardness of all magnesium alloys. Magnesium alloys abrade more rapidly than some other metals when subjected to friction, especially in the absence of proper lubrication. Standard magnesium cast and wrought alloys do not differ appreciably from each other in this respect, the hardest showing only about 15 percent less wear than softer alloys. Under abrasive conditions magnesium must, therefore, be protected by inserts such as plates, liners, sleeves, shoes or bushings, of a wear resisting metal such as steel, malleable iron or bronze, or of non-metallic materials such as fibre or phenolic sheet. Metallic inserts are particularly desirable when the part is operated at elevated temperatures. The inserts may be fitted mechanically to the machined part by pressing, shrinking, riveting, threading or gluing, or if the part involved is a casting, they may be cast in.

Various methods of inserting cylindrical steel bushings are shown on

Table VII—Recommended Interference Fits for Steel and Bronze Bushings in Magnesium

(Range of interferences are expressed in ten-thousandths of an inch)

Bushing Dimensions		Maximum Operating Temperature of Assembly in Deg. F.											
		Steel Bushings						Bronze Bushings					
O.D. in.	Approx. Wall Thickness, in.	70	150	200	250	300	350	70	150	200	250	300	350
1/2	1/16	2–6	5–9	7–11	9–13	11–15	14–18	2–6	4–8	5–9	6–10	7–11	8–12
1	3/32	3–9	10–16	14–20	18–24	22–28	26–32	3–9	7–13	9–15	11–17	14–20	16–22
2	1/8	6–15	19–28	27–36	35–44	44–53	52–61	6–15	13–22	18–27	23–32	27–36	32–41
3	5/32	10–22	30–42	42–54	54–66	66–78	79–91	10–22	21–33	28–40	35–47	42–54	49–61
4	3/16	13–28	39–54	55–70	72–87	88–103	104–119	13–28	25–40	37–52	47–62	56–71	65–80
5	7/32	18–36	51–69	71–89	91–109	111–129	132–150	18–36	37–55	48–66	58–76	69–87	81–99
6	1/4	24–45	63–84	87–108	112–133	136–157	161–182	24–45	46–67	60–81	74–95	88–109	112–133

Note: Interference fit ranges include machining tolerances and are based on assembling bushing with magnesium part at room temperature. These figures should only serve as a guide since each job has its own problems.

p. 375. When using a shrink or press fit, cold interference should be 50 percent more than for aluminum on account of the lower modulus of elasticity of magnesium. An interference of 0.0005 to 0.001-in. per inch of diameter is usually satisfactory, but interferences up to 0.003-in. per inch of diameter have been used in applications involving high torque stresses. A press fit should not be used in magnesium unless the bushing is properly lubricated.

These values should, however, serve only as a guide because several other factors, such as operating temperature of the assembly, ratio of thickness of the bushing to that of the surrounding magnesium metal, and bushing material, play an important part. For example, a shrunk assembly operating at elevated temperature may require more interference to retain sufficient grip. Such factors as difference in thermal expansion between magnesium and bushing metal, and yield strength and modulus of elasticity of the alloys involved at operating temperature must be taken into account in determining proper interference. A bronze bushing with a thermal expansivity 50 percent higher than that of a steel bushing helps to prevent loosening of a joint at elevated temperature. An extremely thin or thick bushing, in relation to the surrounding magnesium metal, requires reduced interference to prevent permanent deformation of either the bushing or the magnesium part. The recommended interference fits for steel and bronze bushings in magnesium, shown in Table VII may serve as a guide.

Bushings may be cast in in one piece or only a pilot cast in to which the bushing may be attached in various ways. Both types are illustrated on p. 375. The latter method avoids high shrinking stresses in the casting, which sometimes occur with one-piece inserts and is, therefore, preferred in highly stressed castings. Threaded inserts improve anchoring when high thrust is involved and conditions do not permit a cast-in insert.

Lightly loaded ball bearings are generally fitted into magnesium parts with 50 percent increased interference or shrink compared to aluminum. An interference of 0.0003 to 0.0010 in. per inch of diameter, depending on size and type of bearing and operating conditions, is customary. More highly stressed ball bearings and high-precision ball bearings, which would be damaged by such interferences, are not fitted directly in the magnesium, but are seated in steel or bronze bushings as shown on p. 375. Bushings are always recommended for ball bearings more than 3 in. in diameter. The same considerations apply in principle for tapered roller bearings, except that they can be used safely with greater interference, for instance 0.0012 to 0.0018-in. per inch of diameter.

Fig. 9—Checking a magnesium alloy sand casting against blueprint

Heavy metal bearings or bushings may be dispensed with in magnesium alloy bearings when loads do not exceed about 2,000 lb. per sq.in. and shaft speeds are slow and when operating temperatures do not exceed about 230 deg. F., providing the steel shaft is case-hardened and highly polished, and adequate lubrication is provided. Examples are camshaft bearings in aircraft engines and lightly loaded bearings, machined from magnesium tubing, in electric motors and textile machinery. Successful experiments with even higher loads have been reported. The use of magnesium alloys for bearings of this type is restricted to those with rotating shafts, although magnesium has been successfully used in tappet guides under conditions of sliding friction.

Various methods of protection for magnesium surfaces against wear and abrasion are shown on p. 375. Some methods are suitable only for a straight or slightly curved surface, others are best suited for a peripheral surface, such as the rim of a wheel. Spraying with iron is effective, but unless a dense coating is produced galvanic corrosion may occur in the joint.

Chemical coatings have little effect on hardness and wear resistance, except AMC Treatment O which has a moderate hardening effect. Chromium plating or other electro-chemical methods for producing a harder surface have not yet been successful on a commercial basis. In regard to smudging or crocking, for instance in contact with yarn or paper, magnesium alloys are usually satisfactory except at elevated temperature. Any chemical coating to be listed in Part III improves resistance to smudging. Borax and sodium hydroxide treatments are preferred while dichromate dip and chrome-alum are least effective. A hard wax coating helps further to prevent smudging. Where such

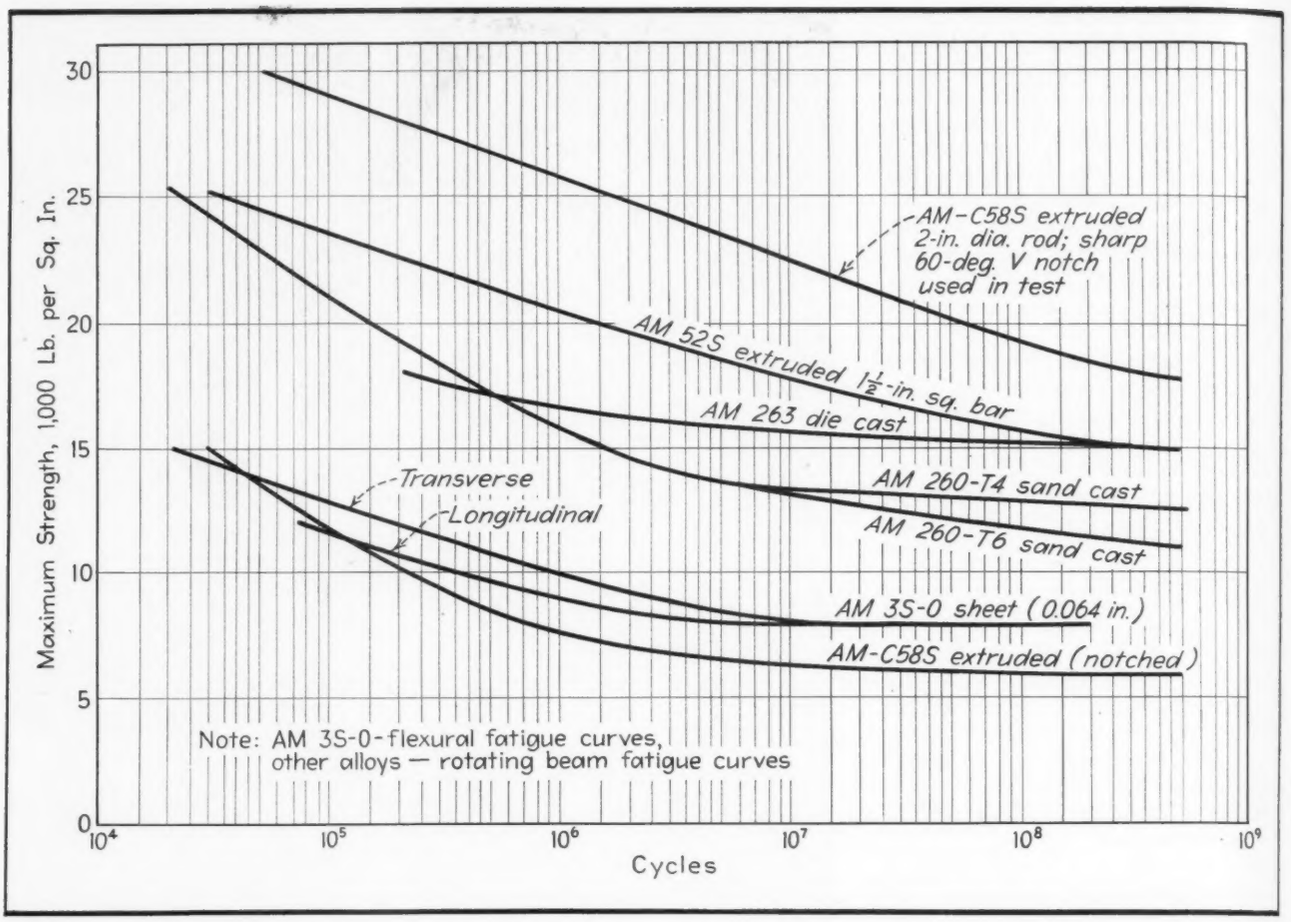

Fig. 10—Fatigue curves of some magnesium alloys. Casting defects materially lower fatigue strength

measures do not suffice, a steel or bronze member or one of an anodically coated aluminum should be attached to the magnesium section. Resistance to nicking can be attained by inserts of stainless steel, laminated paper-base phenolic sheet or similar plastics.

Resilience and Toughness

1. Resilience. The capacity of a material for shock absorption within the elastic range, known as resilience, increases in direct proportion to the square of the stress applied, and in inverse proportion to the modulus of elasticity. As an example, for a bar axially loaded in tension this relationship is expressed by the following formula:

$$W = \frac{Pe}{2} = \tfrac{1}{2} Af\left(\frac{fL}{E}\right) = \tfrac{1}{2}\left(\frac{f^2}{E}\right) AL$$

where

W = external work performed on bar, in. lb.
P = load, lb.
e = deformation of bar, in.
A = cross sectional area, sq. in.
f = stress, lb. per sq. in.
L = length of bar, in.
E = modulus of elasticity, lb. per sq. in.

For constant volume, the energy absorbed becomes

$$W_2 = \frac{Kf^2}{2E}$$

where:

K = constant indicating cross-sectional area and length of bar

Because of their low modulus of elasticity, magnesium alloys have a relatively high resilience. Energy values based on one-half of yield strength, a customary design stress, are significant for applications in which the energy to be absorbed is known in advance.

The energy absorbed at the proportional limit of the material has been defined as the modulus of resilience. Because of the difficulty of accurately determining the proportional limit, which has been pointed out before, no values for the modulus of resilience are given.

2. Toughness. If an impact blow is sufficiently strong to cause appreciable permanent set, the impact resistance of the member is determined primarily by strength and ductility of the material. This property, known as toughness, is determined from the area under the stress-strain curve of the material. In the absence of complete stress-strain curves, an approximate value of toughness is the product of tensile strength times maximum deformation:

$$W = f \cdot e$$

where:

W = work required for rupture, in. lb. per cu. in.
f = ultimate tensile strength, lb. per sq. in.
e = deformation at point of rupture, in. per in.

Typical toughness values of structural materials, computed on this basis, are given in Table IV. The principal importance of toughness values lies in designs where failure, if it occur, should follow extensive plastic deformation rather than be a quick break.

3. Notch Impact Strength. If failure of a structural member under shock load is accelerated by a stress raising factor, such as a notch, magnesium alloys suffer because of notch sensitivity, as will be discussed later. Notch impact tests customary for some other metals, such as the Charpy and Izod tests, have little correlation with actual service results. Such tests fail to take resilience into account. Resilience softens the blow and, there-

fore, materially influences the result. The subject is discussed by J. E. Sullivan, in Technical Note No. 560, N.A.C.A., 1936.

Resistance to Fatigue

Magnesium alloys have good resistance to fatigue but are, in common with other metals, sensitive to the effect of notches and other stress raising factors, which reduce their endurance limits considerably.

1. Endurance Limit. Endurance limits of various structural materials, as determined by the R. R. Moore type rotating-beam test, are given in Table IV. Fatigue curves of several magnesium alloys are shown in Fig. 10. Casting defects such as microshrinkage materially lower fatigue strength of magnesium alloy castings.

Endurance limits reported in Table IV are based on a stress cycle passing from maximum tension to maximum compression and back to maximum tension. If the range of the stress cycle is between zero and maximum tension or between two tension values, the safe range of stress is less, as shown in Fig. 11. Thus, fatigue strength of an 8.5Al-0.5Zn-0.2Mn magnesium-base alloy in wrought condition (similar to AM58S) for about 50,000,000 cycles of completely reversed stress was found to be 20,000 lb. per sq.in., corresponding to a total range of 40,000 lb. per sq.in. The same alloy develops a fatigue strength of only 28,000 lb. per sq.in. when cyclically stressed between zero and maximum tension, or 70 percent of the range for complete reversal of stress. For some other magnesium alloys, the corresponding percentage varies between about 60 and 80 percent.

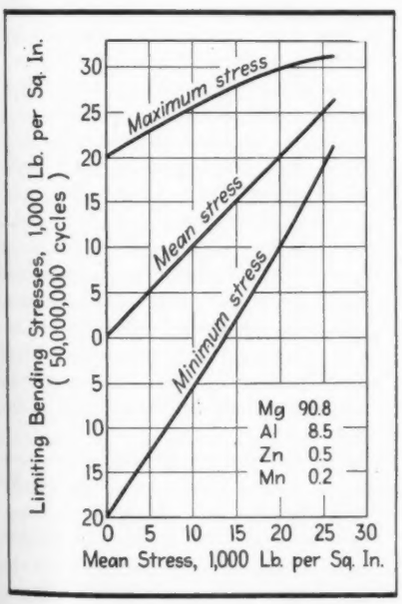

Fig. 11—Bending fatigue strength of extruded magnesium alloy containing 8.5 Al, 0.5 Zn, and 0.2 Mn (50,000,000-000, cycles of stress).

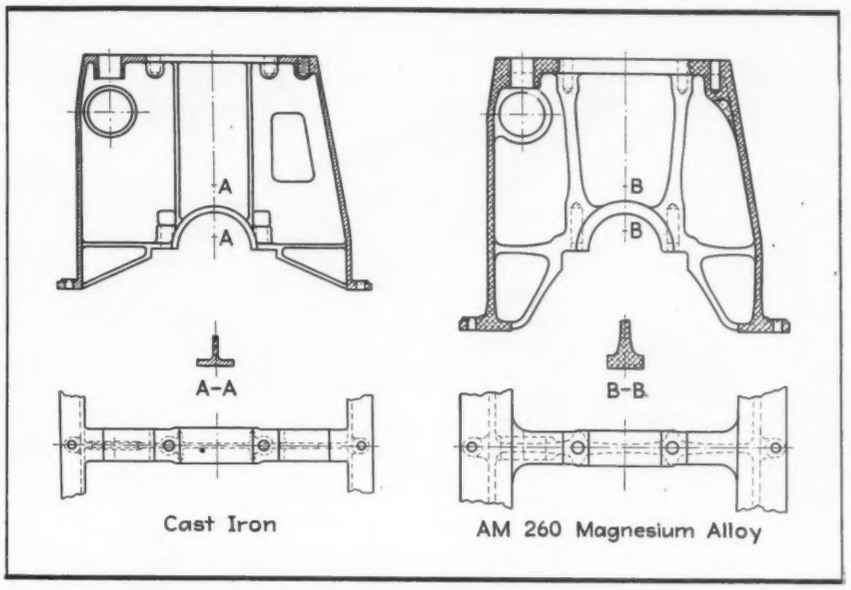

Fig. 12—Types of design that give high resistance to fatigue. Rigidity of the magnesium crankcase wall at least equals that of the cast iron wall

2. Effect of Notches on Endurance Limit. For design purposes, factors that are not included in the standard rotating-beam test also have a bearing on fatigue life of a structural member. The most important of these are stress raisers, such as sharp notches, which materially reduce fatigue life. The effect of surface quality is illustrated by tests with specimens of the AM265-C alloy type, tested with their cast skin, which showed an endurance limit of about 6,000 lb. per sq.in. as compared to a value of 8,500 lb. per sq.in. for standard machined and polished specimens. Scraping and shot blasting the skin raised the endurance limit to 7,500 and 8,500 lb. per sq.in. respectively. Standard AM-265-C and 2-in. dia. extruded AM-C-58S magnesium test bars with 60-deg. notches lost about two-thirds of their endurance limits, and cast AM240-T4 and AM240-T61 alloys lost 32 and 25 percent of their endurance limits respectively. Heat-treatment may reduce notch sensitivity of some alloys.

A severe notch effect, caused by a cast-on bead in the center of a standard magnesium alloy test bar, probably not heat-treated, machined with a sharp re-entrant corner, reduced fatigue strength to about one-half the notch-free fatigue strength. An $\frac{1}{8}$-in. radius in the re-entrant corner of the bead increased fatigue strength. These results were reported by H. Altwicker in *S.A.E. Journal*, Sept. 1939. Notch impact fatigue tests of the Stanton type show the impact fatigue strength of AM240-T4 magnesium alloy at 1,000,000 blows to be 0.025 ft.lb.

Magnesium is susceptible to effects of stress concentration, in common with all other structural materials, but to a somewhat higher degree. The term "stress concentration" covers not only such obvious stress raisers as notches, sharp corners, burrs, knife-edge effects, etc., but in a broader sense any faulty designs involving locally over-burdened sections of a structural member. The measures to be taken to guard against notch effects are well known. They include large fillets, beading of holes and rounding of sharp corners in highly stressed sections, and careful blending of joints of sections that carry main stresses. Examples of notch effects, which in highly stressed members may prove harmful, are chisel marks caused in trimming, scribe marks originating in the lay-out room, or unintended cutings during machining. Examples of faulty machining practice which may lead to fatigue failures are shown on p. 374. All of the measures that help to eliminate stress-raising factors are good design in all metals.

The bearing wall of a truck engine crankcase, shown in Fig. 12, is an example of the types of design that give high resistance to fatigue. Rigidity of the magnesium crankcase wall at least equals that of the cast iron wall. Stress-raising influences have, as far as possible, been eliminated. On p. 374 are a number of examples designed to increase fatigue strength.

The man who made this drawing showed, by his samples, that he had an exceptional sense of values when making wash drawings because his samples were scenes of air warfare in the First World War

Organizing A Graphic Illustration Department

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Establishment of a graphic illustration organization calls for a point of view that is foreign to the usual thinking of an engineering department. The type of personnel, consisting of commercial artists who must be trained to think like engineers, makes such a group at first seem out of place in an engineering department atmosphere. How to set up such an organization is described in this article. The making of such drawings was described in PRODUCT ENGINEERING for March, pages 131-137.

BEFORE a tentative organization for making visuals, as graphic illustrations are called, is set up, the principal reasons for use of such drawings must be made clear. In the past their principal use has been for production and training purposes, to show assembly crews and trainees what the units they are putting together look like. Such drawings are called production illustrations and were the original manifestation of visuals. Now, however, their applications have been expanded to the point where they can be used in practically all phases of operation of an industrial concern.

Basically, the graphic illustration department resolves into three divisions, typified by the supervisor, assistant and apprentice. Whether the department consists of 3 or 300 people these divisions are necessary.

After the scope of the new department's activities is established the next step is to hire a supervisor or department head who is capable of grasping the ramifications of the problems involved, can do the work himself when necessary and knows how to pick the right personnel for the department. The supervisor should be someone experienced in, or at least familiar with, graphic illustration. He should have a fairly broad experience in commercial art. Industrial catalog artwork is a not-too-distant relative of the type of drawings that will be produced. Industrial design, especially in the heavier industries, is even more closely related. A smattering of engineering training will be extremely helpful, but only luck turns up this type of person. During the past year we found that approximately 5 percent of the commercial artists interviewed had a year or so of engineering at one time or another. At the very least, however, the supervisor should be able to read blueprints and talk in engineering terms.

The assistant should be of similar qualifications, with the possible exception of executive ability. It is good policy to let the supervisor select his own assistant, especially if he has held executive posts in the past, and since artistic ability is a prime requisite in all the department's personnel the supervisor is better able to judge this ability than someone who is not an artist. However, regardless of what hiring procedure is worked out, the supervisor should always make the final choice.

Apprentices may be either male or female. Quite likely they may come direct from art school, although sometimes it is possible to find candidates who have had brief experience in some phase of commercial art following formal training. The same general qualifications as the supervisor and assistant are necessary for the apprentice, but to a lesser degree.

In hiring the supervisor and his assistant there will be many samples of artistic effort offered. These will include samples of art school classwork, architectural renderings, fiction illustration, poster design, oilcloth and textile design, men's fashions and advertising layout, as well as work that is more in direct line with graphic illustration. It is a safe assumption that if the trend of the applicant's samples shows a definite interest in the products with which he will be dealing, or related fields, this man would be capable of absorbing and perhaps even anticipating requirements in graphic illustration. At the same time, if his work does not follow this pattern and his samples are of an entirely unrelated category, there is no reason to suppose that he will not be satisfactory.

As an example of the diversified types of artists that can be trained successfully in this new branch of industrial art, we have in our department a former department-store fashion illustrator; a former designer of greeting cards and gift wrappings; a combination cartoonist, show-card-writer and window-dresser; as well as artists representing virtually all of the other fields of commercial art.

Strangely, architectural rendering is not so closely related to visualizing as one might think. Although certain classifications of architectural draftsmen can be converted to graphic illustration, for the most part their work is too loose and their training in perspective limited to very few shapes and a minimum of views. In contrast to the average commercial artist, who must be able to handle the full range of mediums, the architectural draftsman usually has been trained in only a few.

Other possible sources of visualizers are the many art schools now giving special training in this type of work. However, the school's reputation is not sufficient evidence of the thoroughness of its training program. If apprentices are being hired, any accredited art school can recommend suitable candidates from among those who have completed the course. But if a supervisor or a basic assistant is being sought it would be best to find out exactly what training is included in the course given by the school to be contacted, as well as the eligibility requirements.

Most of the production illustration courses recently added to the curricula of art schools and colleges are sadly inadequate. Obviously, with much confusion in the application of production illustration in industry itself, the schools have access to little information to guide them in outlining a satisfactory training program. Many of the schools are offering these courses to students and beginners who have only a minimum of art training and little or no commercial experience. Most of the courses do not even cover the bare essentials, mainly because the instructors selected are not thoroughly acquainted with the more progressive uses of production illustration in actual practice.

There are a number of schools on the West Coast which are cooperating with the larger aircraft companies, and whose courses are completely adequate. On the East Coast the Grand Central School of Art, in New York City, and in the Midwest the Illinois Institute of Technology have approached the problem in a manner with which we are thoroughly in accord. Their requirements for eligibility are on a par with our own requirements for additions to our present staff; their students are, for the most part, well-grounded, experienced commercial artists; their instructors are graduate engineers and industrial designers who have had a wealth of experience in production illustration; and the curriculum of the course parallels the training we give to our own new artists. They have wisely kept the curriculum sufficiently flexible to handle each trainee individually. Among the subjects covered in this particular course, and which we consider absolutely essential, are blueprint reading (a must); isometric projection; formal perspective; AN, NAF, and NAS standards; general drafting room and engineering practices; actual problems in design development illustration and production illustration; and examples of the uses of graphic illustration as various companies have applied them.

We should like to point out that by formal perspective we do not mean the involved perspective projections on which some schools are basing their curricula. We have found most mechanical projections complicated procedures which generally result in distortion. In other words, after going to considerable time and trouble to project by these methods the resultant shape is not a true portrayal of the object as the eye would see it.

In actual practice, much simpler methods may be used which, besides speeding the output of perspective drawings, have the advantage of being readily taught to the average commercial artist in a few weeks. There are simplified formal perspective methods in use at the present time which make it possible to scale every detail of a drawing in true perspective, whereas the more complicated methods which are based on theory alone permit only the projection of general contour. They would be far too difficult and time-consuming to warrant projection of details.

Experience has taught us that several ratings for visualizers are useful, particularly as a morale-boosting mechanism. An increase in salary accompanied by promotion to a higher rating does a lot more for morale than the pay increase without the corresponding advancement. Therefore, in anticipation of expansion of the group being organized ratings should be established from the start. These ratings may well parallel the subdivisions for draftsmen. In our department we have group leaders; assistant group leaders; A and B graphic layout men; A, B, C and D graphic detailers; and apprentices. The type and importance of the work done in each rating depends, of course, on the department's activities.

In self-defense, however, we should like to point out that this method of rating engineering artists may not be adequate insofar as the maximum salary rate is concerned. Some key men will have had intensified art education fully the equivalent of the education required for an engineering degree, as well as intensive commercial experience in their own field of endeavor. Logically, then, after they have applied themselves to engineering illustration to the point of qualifying as veterans—or key men—they should be reclassified according to ratings for engineers of similar background.

As further amplification of this point, we should like to mention an incident that occurred recently. One of our veteran illustrators was putting the finishing touches to a complicated design-development master layout of a complete airplane in *accurately scaled perspective*, showing all fuselage, wing and tail surface stations as well as complete details of canopy, landing gear, etc. We use these perspective master layouts for laying out controls, hydraulic and electrical systems, exploded views and a variety of other purposes because clearances and interferences can be determined more readily in perspective layouts. One of our "A Layout" draftsmen stopped by to admire the drawing, and with every good intention of extending a compliment, told us, "If Blank can do that sort of work you should have him *promoted* to a layout drafting job."

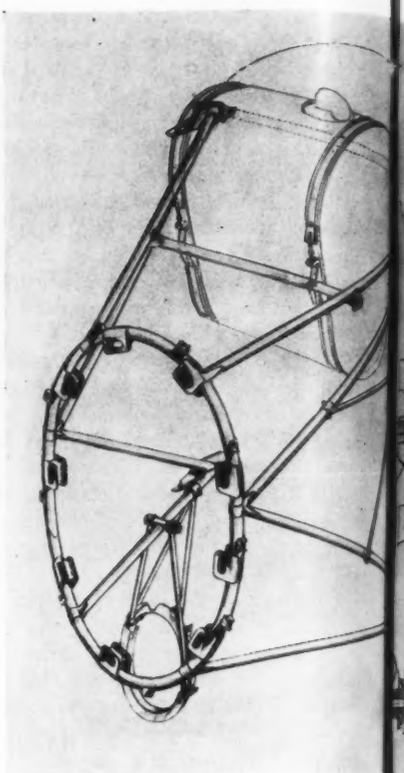
There is considerable doubt that

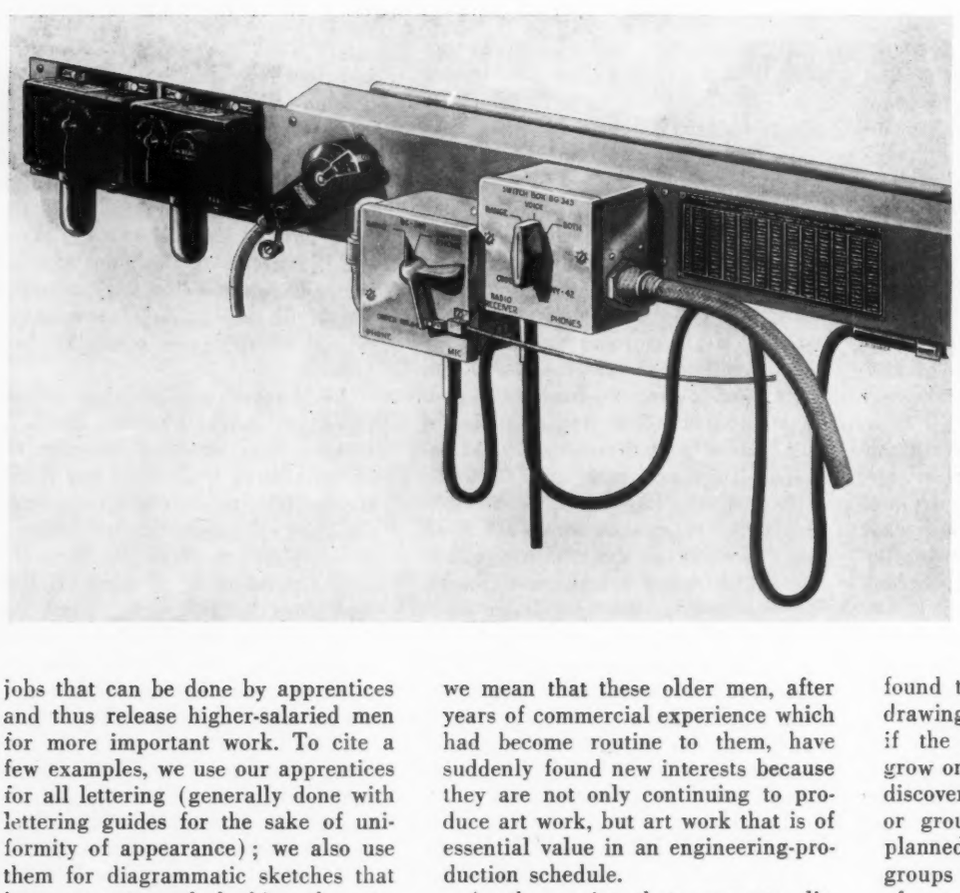
we should have considered such a transfer a promotion. What the draftsman hadn't taken into consideration —and it is a common fallacy—was the fact that, whereas we have several veteran graphic illustrators who, in spite of a minimum of formal training in drafting, if any, are fully capable of doing layout drafting, it is extremely doubtful that any layout draftsman could handle an assignment in scaled perspective of the magnitude of this particular drawing without considerable training. The average artist rapidly absorbs drafting knowledge. It has been our experience that an artist can complete an isometric projection in a fraction of the time that most draftsmen would require, and accurately scaled perspective is a much more advanced problem.

There are any number of ways in which an apprentice can be valuable. With the proper background and proper interest he (or she, for that matter) immediately becomes a potential basic assistant or worker. There are plenty of odds and ends of jobs that can be done by apprentices and thus release higher-salaried men for more important work. To cite a few examples, we use our apprentices for all lettering (generally done with lettering guides for the sake of uniformity of appearance); we also use them for diagrammatic sketches that lean more toward drafting than toward perspective illustration—not because we consider drafting less important but because we are convinced that this is one of the better ways for the apprentice to strengthen the engineering side of his training. Changes and corrections on illustrations which have already been released are excellent stepping stones toward familiarizing the apprentice with our work. Furthermore, there is always a certain amount of filing of drawings and blueprints to be done that can be handled by the apprentice as a fill-in job. This assignment is an important part of the training because it gives the apprentice a thorough understanding of the drawing numbering system as well as the handling of change notices and engineering orders.

Of additional interest is the fact that the age of employees in our department varies from the youngest apprentice of 19 to the oldest man of 57. We have found that "old dogs *can* be taught new tricks." The men over 50 in our department have not only brought with them their master craftsmanship and their steadying influence on the younger, more impressionable artists but they have also demonstrated a remarkable ability for acquiring a "second wind." By that we mean that these older men, after years of commercial experience which had become routine to them, have suddenly found new interests because they are not only continuing to produce art work, but art work that is of essential value in an engineering-production schedule.

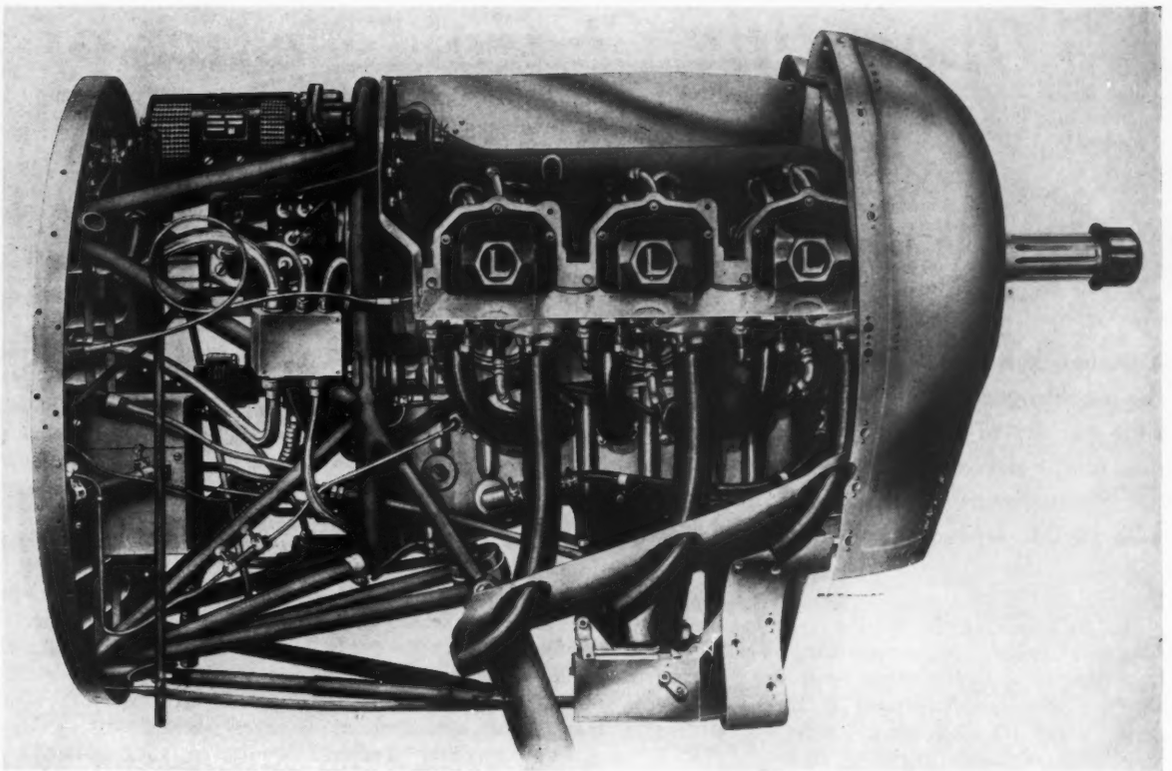
Another point that warrants discussion is the relative size of the department and ultimate scope. As the department begins to take hold and drawings are turned out it will be found that demands for this type of drawing will normally increase even if the department is permitted to grow only as its potential benefits are discovered by other department heads or group leaders. However, with a planned program of educating all groups concerned in the possibilities of graphic illustration as related to their own particular functions the approach toward maximum efficiency in the graphic group can be hastened. For example, service engineers must





When the man who made the above drawings applied for a job as graphic illustrator he submitted several samples of department-store newspaper advertising art showing men's clothing. The attention to detail and his ability to make wash drawings, coupled with his experience in working to deadlines, showed that he would probably make a good visualizer. The first visual that he made, above, indicated that the choice was a good one. The work he does now is shown at the right

Besides attention to detail the man who made this graphic showed by his samples that he was very accurate in all details



realize the availability for illustrating handbooks; design development engineers must be taught the numerous advantages of visualizing new designs in three dimensions; group leaders must be shown the advantages of three-dimensional assembly drawings as opposed to two-dimensional assemblies; estimating, planning, inspection and similar departments should be informed that perspective rendering will clarify the visualization of engineering drawings; executives should be offered reproductions in convenient sizes for conference purposes.

The uses mentioned above for graphics have not yet taken us out of the engineering department. The value of perspective drawings to the unskilled, semi-trained production worker has been the one aspect of their use that has received the most publicity. But this is actually only a part of the wide-spread possibilities of three-dimensional visual aids. By calling attention to these facts rather than waiting for them to come about haphazardly the department will not only be built up at an accelerated tempo but a constant demand will be maintained that we can guarantee will leave no room for dull moments for the new artists. Most commercial artists flourish under pressure. The morale and enthusiasm of these men will rise and fall in direct ratio to the demands for their work. It is not at all difficult to maintain such conditions with a graphic illustration group which represents from 5 to 15 percent of the total engineering department payroll, the latter figure being predicated on the more advanced uses of visuals for all assemblies, subassemblies and a high percentage of design-development work.

Since a new graphic group—of minimum size—will be handling work that is related to many different functions of the entire engineering department, it will probably be established as a definite unit on the same footing as the other engineering groups. Further expansion, however, will prove the feasibility of having *experienced illustrators* assigned directly to engineering groups for the duration of the project on which each group is working. Obviously, as the heads of these groups are not too familiar with the methods or applications of perspective drawings it would be unwise to assign the same illustrators permanently to them, with responsibility only to the particular group leader. In our opinion, a more satisfactory arrangement is to have the illustrators work from an operational center, retaining a flexibility of assignment so that they may be shifted with the work load. The greater percentage of assignments will not be specifically for any one group but, rather, will be of the type which can be handled most efficiently from the operational center.

Accuracy of detail will naturally be the responsibility of the group leader to whom the illustrator is temporarily assigned, but in order to maintain a unity of purpose and style as well as a high standard of rendering, final authority should rest with the graphic supervisor. Just as it has been pointed out that a supervisor of art-director calibre can select potential illustrators from radically unrelated samples of work, he will also be able to assign his men to the type of assignments for which they are best fitted. It is only through a unified illustration group setup that necessary experience can properly be obtained.

The effectiveness of a graphic illustration organization is limited only by the use made of it, when the right kind of personnel is chosen. We have some first-rate men and women on our staff and we know that these people are capable of bigger and better things. Despite the many uses made of visuals throughout the Fleetwings organization we are even now contemplating progressive developments in their use beyond anything we dreamed of only a year ago. The ultimate scope of our group is still somewhere in the distance.

Artists as a whole are no more temperamental "glamour boys" than draftsmen or any other group of specialists. In fact, the facility with which deadline-conscious commercial artists can put craftsmanship into draftsmanship will be surprising.

Operating Characteristics of Electric Motor Drives

L. H. BERKLEY
Electrical Engineer

Although the author has taken the problem of design for drives for machine tools, the basic principles covered can be applied to a wide variety of machine drives. Besides the customary a.c., and d.c. motor drives, there are drives using electronic control, those using conversion equipment with a.c. power source, and drives with variable-speed mechanical transmission.

SELECTION of the proper type motor drive presupposes a knowledge of the load characteristics and the outstanding features of the drive under consideration. Drives may be classified by various characteristics such as constant horsepower-speed, constant torque-speed, varying torque-speed, and combination of constant torque and constant horsepower characteristics; direct or alternating current for primary power.

Speed characteristics may be termed constant speed, multi-speed, adjustable, varying- or adjustable varying-speed, with speed ranges to infinity secured through a definite number of steps, or stepless variation. The service may be obtained through reversing or non-reversing drives.

Load Characteristic

A drive and its control must be selected to satisfy load requirements under all conditions of torque, speed, and accelerating duty. A major factor in determining whether or not a certain type of equipment can be used to drive a load is whether or not the torque-speed characteristic of the load can be satisfied by that of the drive. Obviously the torque delivered at each speed must equal or be greater than the torque required by the driven load.

Consider the load-characteristic of the main drive motor of a machine tool such as a lathe or planer. As the cutting speed is decreased, the depth of cut is increased, thereby increasing the torque required for driving the load. Since power is proportional to the product of torque and speed, the power required is about constant and the load characteristic approximates a constant-horsepower curve. This is to be expected since the volume of metal removed per minute is approximately constant over the speed range.

Also, consider a core type paper-winding machine. As the thickness of the roll increases, the speed of the driving motor must be reduced in order to keep the sheet tension and linear paper speed constant. Constant tension at constant linear speed means constant horsepower over the entire range, regardless of how the motor-speed varies with the roll diameter.

With a chain grate stoker, belt conveyor, crane or hoist, speed adjustment is required to vary the amount of material being transported. The total pull at any time will be constant and independent of the speed. Therefore, the torque load on the motor is constant. The running characteristic is shown by a constant-torque curve.

The third type of characteristic is the variable-torque curve for drive equipment such as fans, blowers, centrifugal pumps where torque requirements increase with speed. In variable-torque drives, the torque may or may not vary with a fixed power of the speed.

Multi-speed motors are available with different coil windings to give all three load characteristics—constant horsepower-speed, constant torque-speed and varying torque-speed.

A combination form is the constant-torque and constant-horsepower load characteristic. It is found suitable for drives requiring a wide speed range, as where a wide speed range is required such as for elevators and metal working planers. These characteristics will be designated as C.T. for constant-torque; C.H.P. for constant-horsepower; V.T. for variable-torque; C.T.H.P. for combination constant-torque and constant-horse-

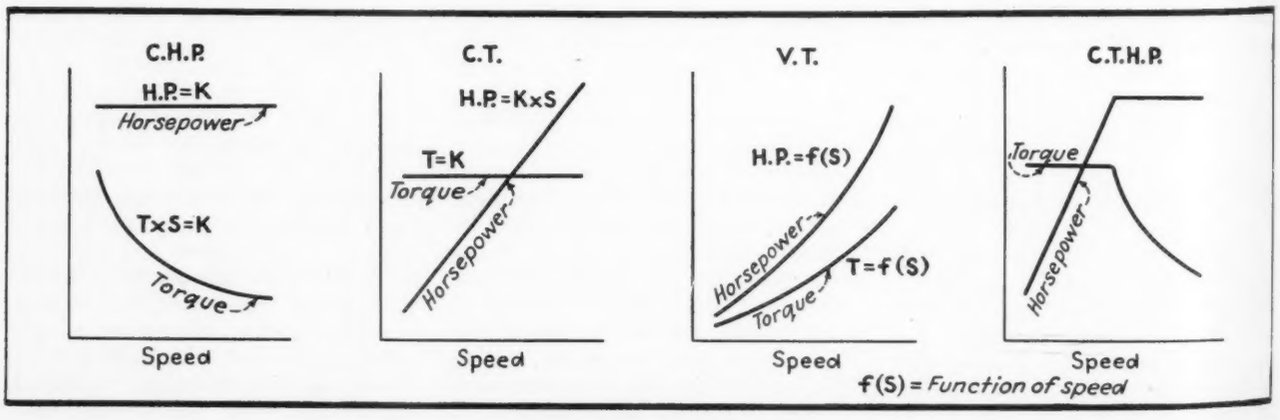


Fig. 1—Load characteristics

Characteristics of Various Types of Electric Motor and Mechanical Drives

Type	Load Characteristics	Speed Regulation	Speed Range	Maximum Size
DIRECT CURRENT MOTOR DRIVES				
Constant Speed				
Shunt wound	Constant Speed	10 percent	Constant	Unlimited
Compound wound	Constant Speed	30 percent	Constant	Unlimited
Adjustable Speed (1)				
By field control	C.H.P.	10 percent, low speed 20 percent, high speed	3:1, 4:1	Unlimited
By armature resistance (2)	C.T.	10 percent, high speed 55 percent, low speed	2:1	50 hp.
Multi-Voltage Balancer Set (3)	C.T.	10–20 percent	Std unit 2:1	
Combination of (1) + (2) or (3)	C.H.P. for field	10 percent at base speed	3:1, 4:1	For (1) + (2), 50 hp.
	C.T. for armature voltage		6 or 8:1	For (1) + (3), unlimited
ALTERNATING CURRENT MOTOR DRIVES				
Constant Speed	Constant speed	5–8 percent, high slip 2–5 percent, standard 8–13 percent, very high slip		Unlimited
Multi-speed	C.T., C.H.P. and V.T. for special applications	2–5 percent	2–3–4 std	Unlimited
Wound Rotor	C.T.	50 percent 65 percent	2:1 3:1	Unlimited
B.T.A. Motor	C.T.	5–10 percent, high speed 15–30 percent, low speed	3 or 4:1	500 hp.
"Polyspeed" Motor	C.T.	15 percent	3:1 — more if forced ventilated	Standard up to 7.5 hp.
"Ajusto-Spede" Motor	C.T.	20–25 percent	4:1 or greater	Std up to 300 hp.
ALTERNATING CURRENT SOURCE WITH CONVERSION EQUIPMENT				
Adjustable-Voltage Drive — Ward-Leonard	C.T. by armature voltage control	15–20 percent	8, 12, or 16:1	Unlimited
	C.H.P. by adding shunt field control	3–5 percent	100:1	Special applications
Variable-Voltage Drive				
Series generator — series motor	C.T.	15 percent	10:1	15 hp.
Multi-Frequency	C.T.	8–10 percent	9:1	Unlimited
Rototrol system of control	C.H.P.	3–5 percent	100:1	Special applications
Thy-mo-trol (Electronic Drives)	C.T.—armature voltage range	1–8 percent	100:1; higher if needed	Standard sizes up to 20 hp.
	C.H.P.—field-weakened range			
Mototrol	C.T. by armature voltage control	4 percent for 10:1 range	20:1 by armature voltage; greater when combined with field control	1 hp. Larger for special applications
	C.H.P. by adding shunt field control	8 percent for 20:1 range		
VARIABLE-SPEED MECHANICAL TRANSMISSION				
Adjustable sheave				
2 sheaves and fixed motor	C.T., C.H.P.			
adjustment by screw	C.T., C.H.P.			
adjustment while motor is not rotating	C.T., C.H.P.			
Graham	V.T.	1–5 percent	Infinite in both directions (without stopping motor)	5 hp.
Morse variable speed	C.T., C.H.P.		8:1; with two-speed motor 16:1	150 hp.
Cone pulley				25 hp.
Hydraulic	C.T., C.H.P.		As large as 500:1	300 hp.

power. Fig. 1 summarizes graphically all four types of these load characteristics.

The primary source of power will be considered as that which comes from the main supply lines and not that which motivates the driving motor. Thus the main power supply may be a.c., but by the use of an a.c.-d.c. converter on the machine, the motivating power will be d.c. Such a system is classified as an a.c. drive. However, recently there has been a considerable increase in the use of d.c. motors, due to greater flexibility.

Four general types of d.c. drives are available:

1. Constant-speed motor-standard type; size unlimited.

2. Adjustable-speed motor—speed change by field resistance control;

C.H.P. (constant horsepower) load characteristic; speed regulation usually 10 percent at low speed to 20 percent at high speed; speed ranges up to 6:1 are approximately the limit.

3. Armature voltage control—speed change by armature voltage control; C.T. characteristic. When run as a fan-cooled motor at speeds one-sixth or one-tenth the basic speed, then because of reduced ventilation, the drive can be operated only intermittently. There are four methods for obtaining armature voltage control:

(a) Control by armature resistance. This control used except in hoisting service with series motors because of poor speed regulation and low efficiency.

(b) With a multi-voltage balancer set, the number of speeds and the speed range depends upon the number of units. Speed regulation is usually 10 to 20 percent. The best field of application of this system is where d.c. power is available.

(c) The Ward-Leonard system uses a motor-generator set with voltage adjusted by generator field control. Because most of these sets are driven by an a.c. motor, this method has been tabulated under a.c. drives.

(d) A thermionic system converts a.c. to d.c. and gives adjustable d.c. voltage. It is under a.c. drives.

4. Combination armature voltage and field resistance control—such drives combine an m.g. set or thermionic system with a field rheostat to give a C.T.H.P. load characteristic. They are tabulated under a.c. drives.

A synchronous motor, an induction motor with small slip, or an ordinary d.c. shunt wound machine may be termed a constant-speed motor. This group includes most of the drives in industrial plants.

The group of varying speed motors includes series motor, induction motor with large slip, and compound wound d.c. motors. These motors are best applied to punch presses, rolling mills, where a heavy flywheel is usually included. A high-slip motor permits the flywheel to slow down, reducing the peak load and the gear strength required.

While the speed of an adjustable constant-speed motor can be varied gradually over a considerable range, when once adjusted, it is practically unaffected by the load. Because of the high cost, maintenance, and large size and weight required by this type of motor, its function has been largely replaced by a.c. drives shown in the tabulation.

In contrast to this motor, there is the adjustable varying-speed motor in which the speed can be adjusted gradually. However, once speed has been adjusted for a given load, it will vary in considerable degree with the change in load. An example is the compound-wound d.c. motor adjusted by field control or a slip-ring induction motor with rheostatic speed control, or a series wound d.c. motor.

A d.c. motor with two armature windings or an induction motor with windings capable of various pole groupings, will provide multi-speed service where the motor can operate at any one of two or more definite speeds, each being practically independent of the load. The multi-speed a.c. motor is commonly used for machine tool, blower, and compressor drives.

Inherent constant speed characteristic of the a.c. squirrel-cage induction motor which is a great disadvantage in many drives, has prompted the development of devices to obtain variable speed when used with the type of motor.

The N.E.M.A. classifications for squirrel-cage induction motors are:

Class A—Normal starting torque, normal starting current, squirrel-cage motor.

Class B—Normal starting torque,

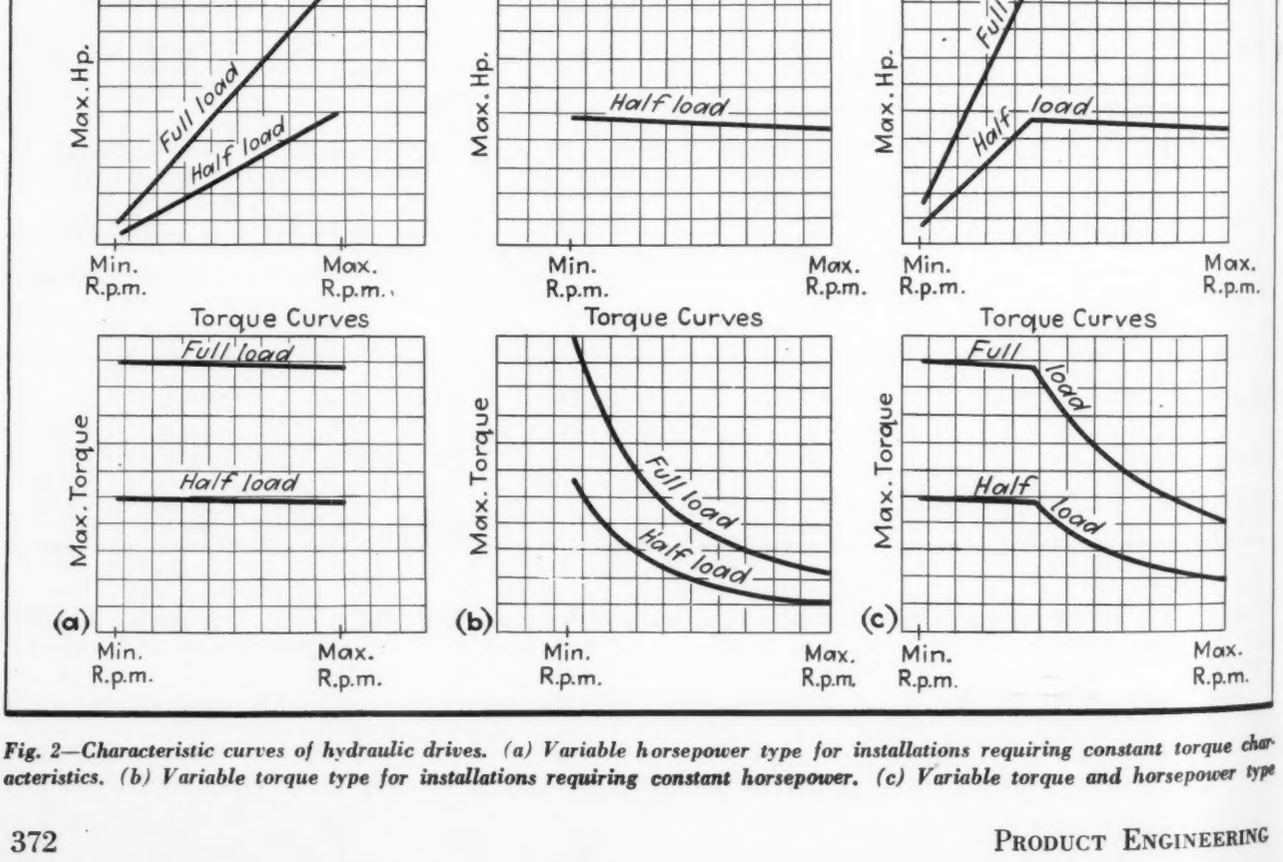


Fig. 2—Characteristic curves of hydraulic drives. (a) Variable horsepower type for installations requiring constant torque characteristics. (b) Variable torque type for installations requiring constant horsepower. (c) Variable torque and horsepower type

N.E.M.A. Squirrel-Cage Motor Characteristics

N.E.M.A. Classification	Starting Torque (percent F.L.T.)	Starting Current (percent F.L.C.)	Pullout Torque (percent F.L.T.)	Percent Slip (at full load)	Percent Efficiency (at full load)	Percent Power Factor (at full load)	Typical Applications
A	100–150	600–800	175–300	2–5	75–93	85–95	Machine tools, fans, blowers, compressors, centrifugal pumps — any application where normal starting torque is satisfactory
B	100–150	400–600	175–300	2–5	75–93	85–95	Same as Class "A"
C	200–250	400–600	175–225	3–5	75–93	85–95	Crushers, plunger pumps, conveyors starting under full load — any application requiring high starting torque
D	275–400	300–500	275–400	7–20	70–85	85–95	Presses, shares, bulldozers, hoists, elevators, and applications having flywheel effect
E	80–100	600–800	100–175	3–5	75–93	75–90	Centrifugal pumps, fans, blowers, generator sets — any application where low starting torque is desirable
F	80–100	400–600	100–175	3–5	75–93	75–90	Same as Class "E"

low starting current, squirrel-cage motor.

Class C—High starting torque, low starting current, squirrel-cage motor.

Class D—High slip squirrel-cage motor.

Class E—Low starting torque, normal starting current, squirrel-cage motor.

Class F—Low starting torque, low starting current, squirrel-cage motor.

Further information on these classifications can be obtained from A.I.E.E. or N.E.M.A. standards.

Speed Range

The speed range required by any variable speed drive, that is, the ratio of the maximum to the minimum speed, approaches infinity:1. Fan and blower drives are usually satisfied by speed ranges of 1½:1, while certain machine tools, such as metal-cutting planers, and elevators, may require speed ranges in excess of 100:1. If a large speed range is required, the choice may be limited down to three or four drives.

Under speed stops, there are two divisions: Drives in which a definite number of speeds are available between minimum and maximum, including multi-voltage d.c. systems, a.c. multi-speed motors, and gearshift drives; and drives which offer stepless speed variation over the entire speed range. Most of the drives previously discussed are in this class.

Each class has its own fields of application. In connection with this, Machinery's Handbook, Tenth Edition, Page 840, states:

"It is of little practical advantage to reduce the speed ratio below 1.2, and in the case of machine tools of ordinary type, a ratio of 1.3 is as small as is advisable. On the other hand, it is inadvisable to let the speed ratio be greater than 1.5, except in the case of cheap machinery, when ratios up to 1.7 may be permissible. In other words, if the lowest speed is 20 r.p.m., the next speed for ordinary machine tools should, as a rule, not be less than 20 x 1.3 = 26 r.p.m., and not more than 20 x 1.5 = 30 r.p.m. Succeeding speeds are found by multiplying each previous speed by the same factor."

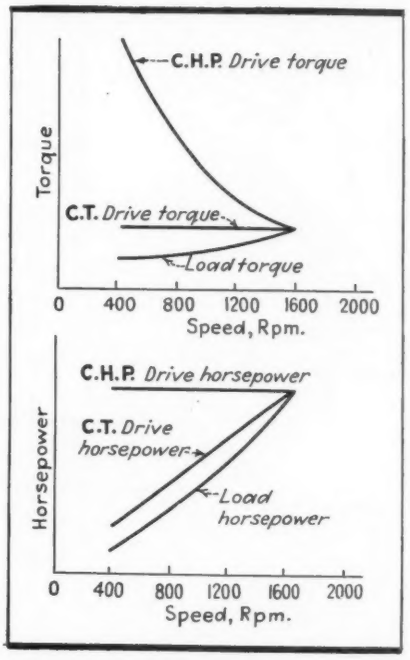


Fig. 3—Load matching a varying torque load

In selecting the drive to motorize a machine tool or any other type of equipment, it is often impossible or uneconomical to obtain the best theoretical load match. A typical example is a reversing lapping machine load which has a V.T. load characteristic and requires stepless speed variation over a 4:1 speed range.

Because comparatively few drives have V.T. load characteristics, a C.T. drive is often used on a V.T. load. First, V.T. or C.T. multi-speed motors and gearshift drives were eliminated because stepless speed variation is desired. Second, adjustable-sheave drives could not be used because of the reversing service. For various reasons, the other types of drives were eliminated, and the choice finally narrowed down between an adjustable-speed shunt motor with field control to give speeds upward from a basic speed of 400 r.p.m., and a general-purpose, variable-voltage drive of the G.E. speed-variator class to give speeds downward from a basic speed of 1,750 r.p.m.

Note that shunt drive would have a C.H.P. characteristic while the variable-voltage drive would have a C.T. characteristic. The effects of using C.T. or C.H.P. drives on a V.T. load is shown graphically in Fig. 3. From a study of these graphs, it is readily seen that the variable-voltage motor comes closer to giving a perfect load match than the adjustable-speed shunt motor. However, a comparison of the costs of both systems indicated that the shunt motor was considerably cheaper.

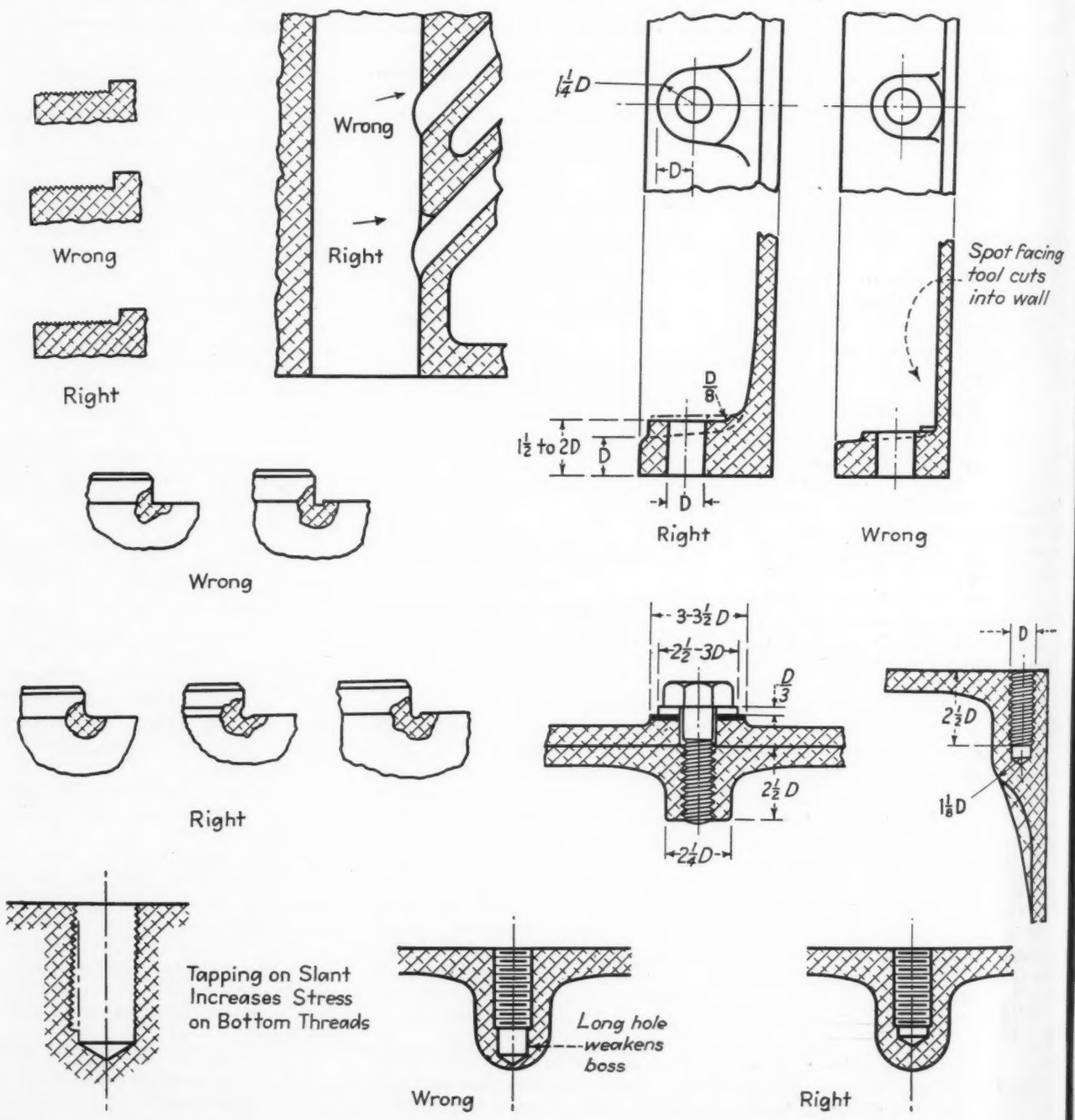
The only operating disadvantage of the shunt motor was the higher inertia of its rotor, because of its lower basic speed, which gave less rapid acceleration and deceleration. This was overcome by using a slowdown limit switch to give full field strength before the reversing limit switch was tripped.

In matching, the economics, as well as the load-characteristics, are important considerations.

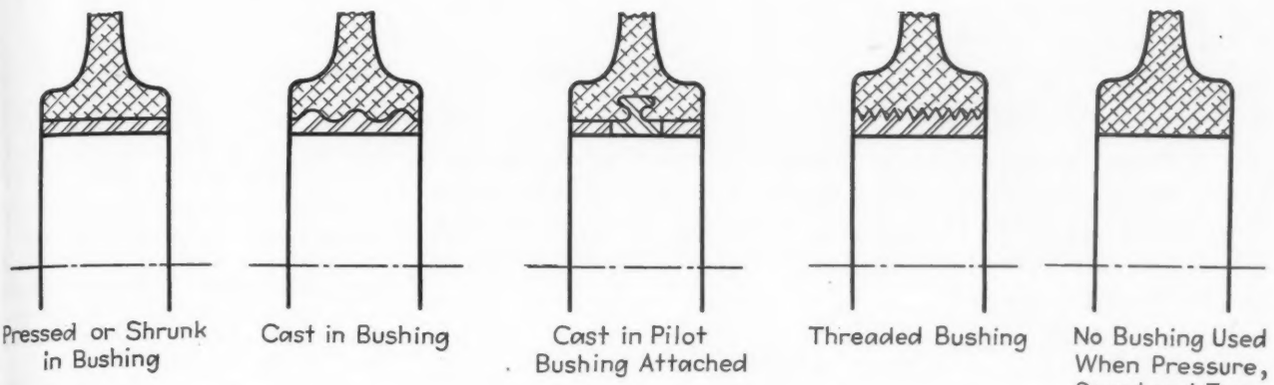
DESIGNING MAGNESIUM PARTS

Magnesium alloys are somewhat more susceptible to concentrations of stress than other structural materials and they abrade more rapidly when subjected to friction, especially without proper lubrication. These tendencies can be checked by careful design in accordance with the accompanying recommended design and shop practice, and by a number of methods of attaching wearing surfaces to magnesium alloy parts. These recommendations are made in a forthcoming book to be published by American Magnesium Corporation in the near future.

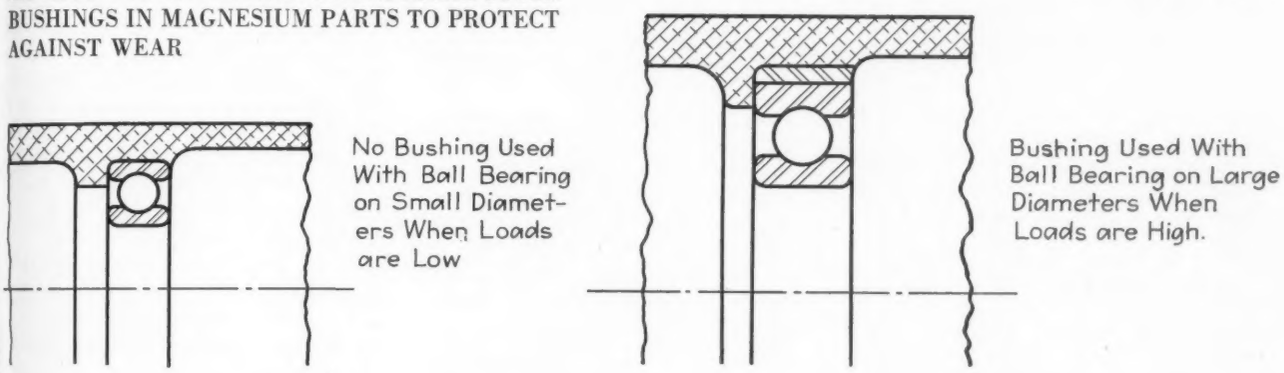
RIGHT AND WRONG DESIGN AND MACHINING PRACTICES FOR MAGNESIUM MEMBERS SHOW HOW TO PREVENT SERVICE FAILURES. SEE ALSO RECOMMENDATIONS FOR ALUMINUM PARTS, PAGES 234 AND 235 OF APRIL PRODUCT ENGINEERING.



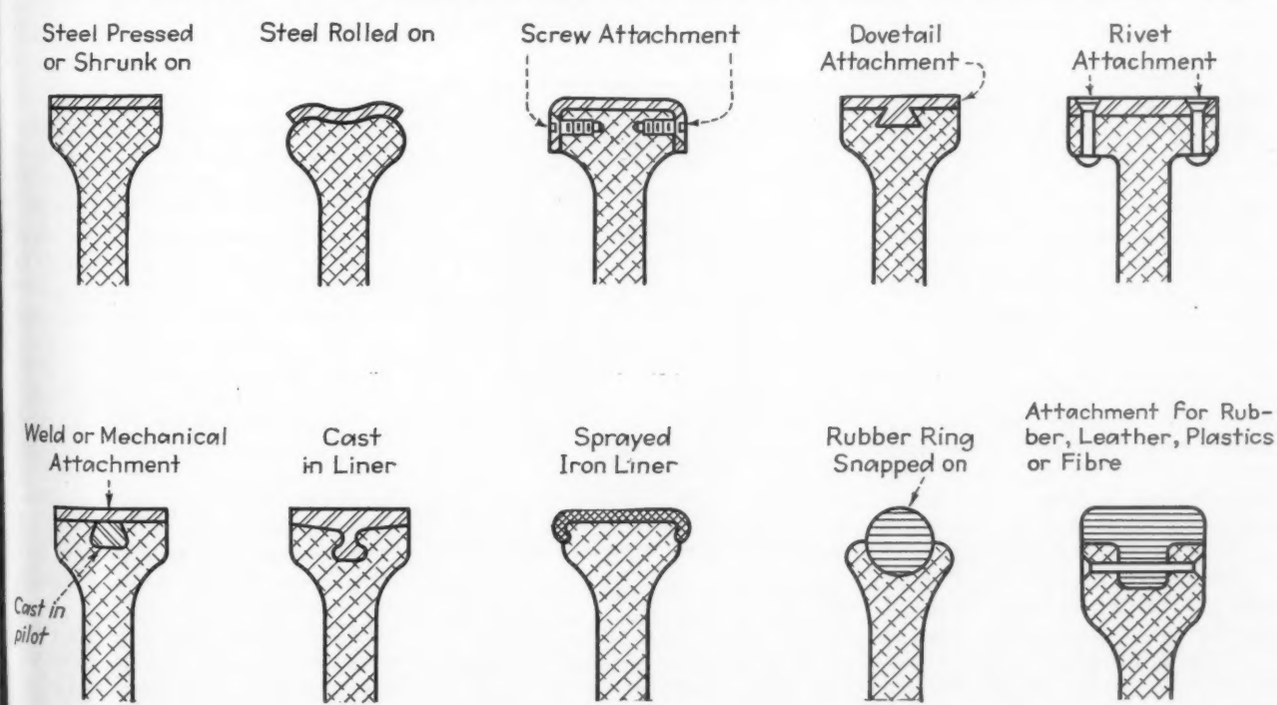
FOR STRENGTH AND WEAR


Pressed or Shrunk in Bushing
Cast in Bushing
Cast in Pilot Bushing Attached
Threaded Bushing
No Bushing Used When Pressure, Speed and Temperature are Low

METHODS OF INSERTING CYLINDRICAL STEEL BUSHINGS IN MAGNESIUM PARTS TO PROTECT AGAINST WEAR


No Bushing Used With Ball Bearing on Small Diameters When Loads are Low
Bushing Used With Ball Bearing on Large Diameters When Loads are High.

METHODS OF PROTECTING MAGNESIUM SURFACES AGAINST WEAR AND ABRASION. DESIGNS APPLY EITHER TO STRAIGHT OR PERIPHERAL SURFACES. ANY WEAR-RESISTANT METAL MAY BE USED.



Factors to Be Considered When Designing Die-Castings — III

HERBERT CHASE

Screw threads and gears can be produced economically as die-castings. The castings may contain inserts. This, the last of a three-part article, presents 12 basic rules for designing die-castings. The article is abstracted from the forthcoming book "Designing for Quantity Production."

GEARS for vending or business machines are generally produced as die-castings. The part may be cast integral with other gears, cams, or pulleys, or the process may be used for producing cast threads. Parts made more economically by other means, can be placed as inserts in die-castings.

To simplify die-casting design, when such items are to be produced, the following twelve rules are presented.

RULE 12: General Shape of Castings: Keep the shape of the casting as simple as conditions permit, avoiding all unnecessary irregularities, and large flat surfaces.

Smooth "streamlined" surfaces, free from all unnecessary projections, are usually favorable from a casting standpoint.

Surfaces of rotation are easy to machine in the die as well as on the casting, and tend to lower costs. Any projections, such as bosses, at an angle to the axis of rotation, even though needed, make the die harder to machine. This is also true when shapes are angular or of odd contours, for some shapes are practically impossible to machine in the die. However, they can be sunk by the hobbing process, an expensive step useful in some special circumstances.

Although castings with large flat surfaces can be cast, it is best avoided for it may be difficult to prevent warpage on cooling. Any large exposed surface is better if at least slightly crowned. Curvature adds strength and stiffness and, if the surface is polished or has a glossy finish, provides highlights to mask surface defects. Large flat surfaces can be "broken" by steps, beads, or other means to reduce such areas and to improve appearance, but beads, steps or crowning should not be adopted when their position involves undercuts or complicates the die.

RULE 13: Tolerances: Never specify tolerances closer than are essential, unless they are in keeping with limits commonly held in die-casting the alloy to be used.

Close limits are specified where mating parts must be held within correspondingly close dimensions, or where unusual precision for locating points is essential. But no useful purpose is served in setting closer limits on dimensions governing fits than are required on mating parts.

Table I (PRODUCT ENGINEERING, April, 1943) gives the closest limits commonly practical to hold in the part as cast.

Where fractional dimensions are used on drawings, it is usual to apply scale measurements or to hold within ±0.010 in. of the nominal dimension unless, for long dimensions, this is closer than can be cast. Die parts must have clearance, and this changes with the wear on the die.

Dimensions can be held within much closer limits, as cast, than for sand castings. Besides, cores are not subject to shifting to the extent common in sand cores.

Dimensional limits are affected by drafts needed to clear the casting from cores and from the die cavity. For example, if a hole diameter is given as 0.500 ±0.005 in., these limits may be held, and may also provide the taper needed. Thus the hole may measure 0.505 in. at the large end, and 0.495 at the small end —the extreme limits allowed. It is a simple matter to ream the hole and to make it straight.

When limits specified are too close to be held in the as-cast form, the caster may elect to hold them by machining. Unless otherwise agreed, the die-caster furnishes castings free of flash.

Dies for alloys of high melting point are subject to checking and must be redressed, if smooth surfaces are to be maintained. This changes the dimensions of the casting and affects to that extent, the limits that can be maintained.

RULE 14: Machining Allowances: Provide sufficient metal at all points, where machining is required, to permit machining within the limits specified.

As with other castings, some allowance for machining is required although the allowance is relatively slight compared with that necessary in sand castings, in part, because a hard scale is not formed. In general, a cut 1/32 to 1/64 in. below the cast surface is sufficient on die-castings. If the casting is so shaped that warpage occurs and has to be corrected by machining, a larger machine allowance is needed.

In general, it is necessary to indicate on the drawing where machining is to be done.

Holes which require tapping are often cored so close to size, that no prior reaming or drilling is needed.

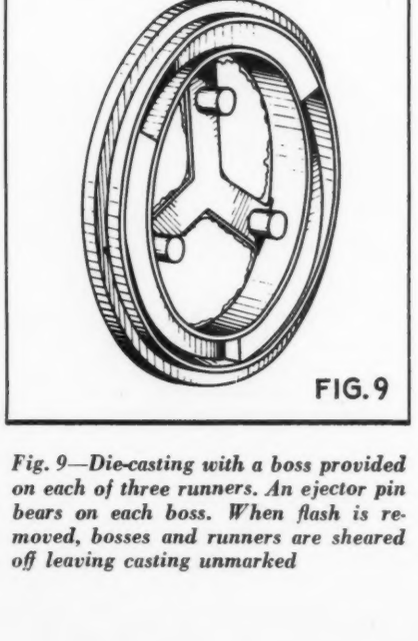


Fig. 9—Die-casting with a boss provided on each of three runners. An ejector pin bears on each boss. When flash is removed, bosses and runners are sheared off leaving casting unmarked

Rule 15: Drafts: Allow ample drafts both on cavity walls and on cores.

Table I gives the minimum drafts commonly recommended. Though drafts can usually be less than for sand castings, they should not be made so small as to interfere with ready ejection of the casting or easy pulling of cores. Castings tend to shrink away from die walls, but if cores or projections come at points between side walls, shrinkage may bind the casting between these elements and make ejection difficult. The casting may be distorted or injured by the pressure on ejector pins.

If drafts are ample, a slight motion frees the casting and makes ejection easier.

Rule 16: Location of Ejector Pins: See that ejector pins are so located as not to leave objectionable marks on the finished casting.

Since the designer of a die-casting rarely designs the die, he may be unable to say where ejector pins will come. He can specify, however, where marks will leave disfiguring blemishes. In some cases, ejector pins may bear upon surfaces which will be cleaned by later machining or upon flash or runners which will be cut away; see Fig. 9.

Rule 17: Integral Fastening Provisions: Employ integrally cast fastening parts wherever their use will lower assembly cost and meet other requirements.

Failure to follow this rule may result in sacrificing an important advantage of die-casting. The usual integral fastenings are projections added to the casting by providing corresponding holes in the die. At assembly, the projections are passed through corresponding holes in a mating part, and are headed, or spun over to effect the fastening.

If projections are a part of the casting, they do not have to be handled separately. Often they can be clinched on assembly by a single blow, especially if a malleable alloy is used. Studs, without threads, are provided to receive "speed nut" fastening devices, which are quickly applied. The usual stud for this purpose is of circular section but if made of D-shaped section, the speed nut is easily removed.

Where both parts to be assembled are die-cast, the holes in one can be cored to mate with projections on the other. Tubular parts of considerable size, cast integrally, can be provided with a thin lip to be spun over after passing through the mating part, or can have threads cut or cast thereon for fastening by a nut. Studs can also be cast integrally and threaded but this is not usually recommended, as a threaded integral stud, unless of large diameter, is easily broken off. Bosses cored for tapping provide a good fastening means in some cases.

Fig. 10—These gears, many integral with other parts, were die-cast and required no machining except, in some cases, removal of some metal in a shaving die

Although integrally cast projections are often provided on the faces of flanges, this is feasible only when the face of the flange from which the projections protrude, does not require machining. Integral projections, for strength, should have at least a small fillet where they join the casting. Axes of the projections should be parallel to each other, and at right angles to the parting of the die.

Rule 18: Threads: Provide for cast threads wherever their use reduces cost over that for cut threads.

There are definite limitations governing the use of cast threads. Most internal threads have to be formed by threaded cores and such cores have to be unscrewed subsequently, which may involve extra work that is likely to slow the casting cycle, unless a rather expensive unscrewing mechanism is provided. Therefore, cast internal threads are used, as a rule, only in zinc alloys, or those of lower melting point; when threads are fairly coarse; and when diameters are over ¾ in. Whatever the pitch, the thread can be carried down to a shoulder, or to the bottom of a blind hole. This is not feasible in tapping. Holes requiring fine threads are tapped and cast but inside threads under ¾ in. diameter are rarely economical.

Threads which come at a parting have a flash which has to be removed by a chasing die or by some special tool. It may cost no more to cut the full thread with a die, than to

cast it and chase it subsequently with a die or other tool.

Rule 19: Gears, Gear Segments, Cams, Etc.: When a gear, gear segment, cam, ratchet or other similar part is needed, consider the possibilities of die-casting it either as a separate piece or integrally with some other part.

Application of this rule often leads to remarkable economies in manufacture.

Several types of die-cast gears, including spur, internal, bevel, helical, and some worm types, can be die-cast with a fairly high degree of precision as to tooth form, pitch diameter, tooth spacing and other dimensions, as indicated in Fig. 10. Allowances for shrinkage and for draft are necessary, but draft for usual tooth length is slight, and may even be zero in some spur and bevel types. When draft is needed, usually it can be removed by the shaving die required to remove flash.

Several gears are often cast integrally in stepped diameters, and with bevel gears or other parts combined. In stepped gears, teeth can end at a face or shoulder, where machining of a one-piece unit would be practically impossible. Gear sectors are made as readily as complete gears. Tooth faces can be made so smooth, as cast, as to be suited for a wide variety of applications. Allowable tooth loading and resistance to wear depend, of course, upon the die casting alloy chosen, its strength, and hardness. Precision is far better than for sand cast gears and, where machining is done, can be close as for blanks of any material.

Rule 20: Combination of Multiple Parts: Design the casting so that it will combine as many parts needed in the completed unit, as conditions permit, and still avoid undue die complexity and excessive casting costs.

Fig. 11 shows how a clock frame can be made from two stamped plates joined by three or four stepped pins. A dial, bosses and other elements are added by subsequent operations. Unless parts of a component have to be made so that they can come apart, or must be separate pieces for some other good reason, they should preferably be made in one piece. Every extra part means, as a rule, needless expense.

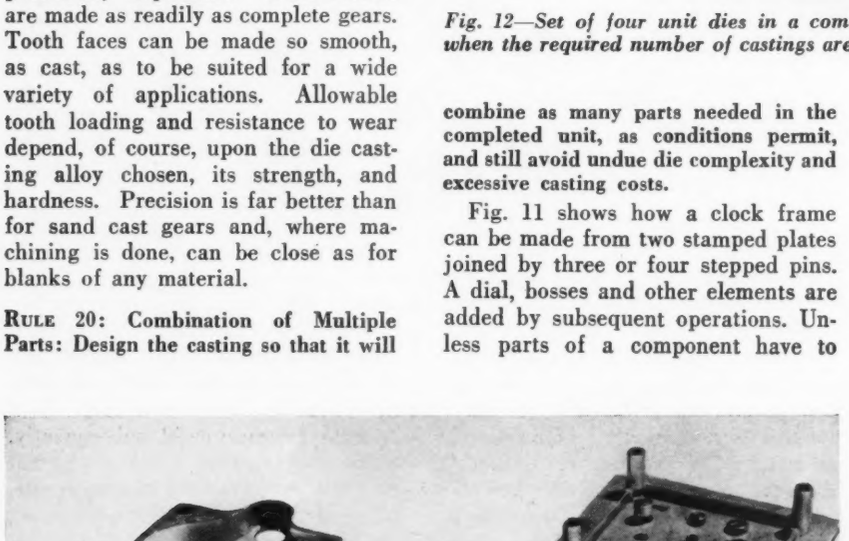


Fig. 11—Two die-castings form this clock frame which is shown assembled at the left. Bosses, projections, and lettering on back of rear plate are all integral parts of the casting

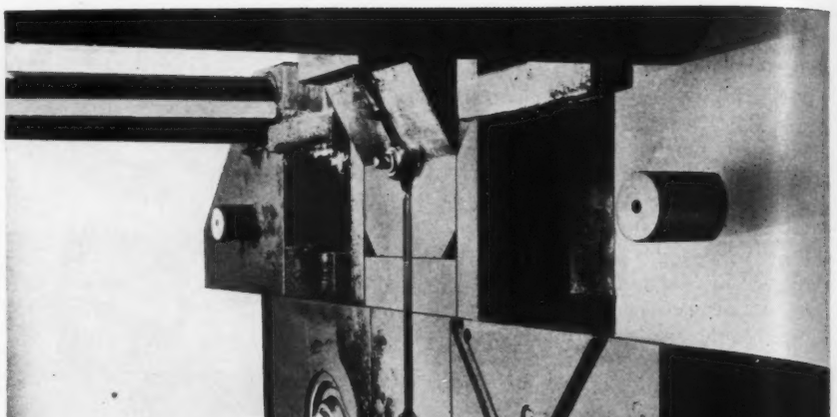


Fig. 12—Set of four unit dies in a comomn holder. Dies can be quickly changed when the required number of castings are produced

Rule 21: Use of Combination Dies: Make use of combination dies wherever cost can be lowered, and other conditions can be met by this means.

Careful consideration should be given to the possibility of simultaneous production of one or more other parts for the same assembly, in one or more other cavities of the same die. This applies especially where the parts are small, and where a combination die is readily made, and simply operated. At each die filling, as many castings are produced as there are cavities in the die. As the work is done at or nearly the same charge for a single casting, considerable economy is realized, even though separate flash removal on each casting of the group is commonly required.

Combination dies are feasible, under some circumstances, when the parts are not for the same assembly. In general, it is better not to use combinations unless the same number of parts are required from each cavity. Otherwise, some of the castings pro-

duced may have to be scrapped. While small unit dies having one or two cavities per die are slightly more expensive, four or more unit dies are commonly filled at the same time, resulting in die economy. Each die need be run only for the precise number of castings required.

Most unit dies are locked in a common frame or chase, Fig. 12, usually holding two to six small dies, and are filled simultaneously. They form, in effect, a single combination die but can be changed individually without changing the entire group. Set-up time, however, may be slightly more than for a single combination die.

Not all castings can be produced in combination dies or even in unit dies. Both types impose certain limitations on size of castings and on the number and position of cores which can be employed. The chief utility of unit dies, and of combination dies, is for small, simple castings in which only simply coring is commonly feasible.

Rule 22: Inserts and Their Utility: Employ inserts whenever their use results in economy, or to secure results which cannot be realized at equal cost by other means.

Inserts are useful when it is required that: (1) Certain parts of the casting must be stronger, harder or more ductile than if the base metal of the casting alone were used; (2) some element is required which it is not feasible to cast; (3) the casting act as a matrix for combining into one unit, a part which cannot be held together so well or so inexpensively by other means or (4) some other special combination of benefits be secured. See Fig. 13.

This rule is applied especially to inserts which are cast in place although it is true, in some instances, for inserts placed in the casting, after the insert is removed from the die. Inserts cast in place invariably add to the cost of the casting, because of the extra time required to place them in the die which, being hot, tends to slow the job of placement.

Inserts should be furnished within close dimensional limits at points where they must fit the die. Inserts are commonly applied either to add greater strength than the metal of the casting affords, or to provide wear resistance through greater hardness or superior bearing properties. Elements as studs, screws, stems, shanks, nuts, bushings, are often cast in place. A flexible element, such as a leaf spring may be added to good purpose, or a dielectric part may be applied.

Wood and even paper inserts have been used, the former to lower the weight, and the latter to provide a good friction surface, as in a pulley or clutch. Slight charring of such combustible inserts may occur from contact with molten metal, but the latter freezes so quickly that the charring is negligible, at least with an alloy such as the zinc type having a medium low melting temperature.

In all cases, inserts must be so made that they can be clamped or otherwise positively positioned by the die, but ejection of the casting should not become impossible.

Some inserts are, except for supporting elements, completely buried in the casting. In most cases, they are partly exposed or protrude from the casting. The inserts must be so made that they can be clamped or otherwise positively positioned by the die. Except in rare cases, the insert should be so constructed that if it is inadvertently left out of the die, molten metal cannot be ejected through this opening in the die. Another precaution is that the insert when used, should not hamper the ejection of the casting from the die.

Most inserts are knurled or are provided with grooves, which when filled with metal, become anchored in the casting. Inserts should always be so fixed, if subjected to stresses.

Hardened parts, such as cutter blades or springs, or bushings, can be cast in place without losing the temper, as the molten metal cools too quickly to cause the temper to be drawn.

Rule 23: Appearance: Design the casting so that, consistent with other requirements, its appearance will be pleasing and will blend with that of mating parts.

Other things including price, being equal, the better appearing product greatly outsells that lacking good appearance.

Appearance is enhanced by simplicity of line and form, rarely by an embellishment applied only for decorative purposes. If the engineer does not possess artistic ability, he should leave the matter of appearance to an industrial designer. The proper combination of strength and ability to perform should not be sacrificed merely to gain good appearance. No sacrifice need be made where the engineer and the artist cooperate.

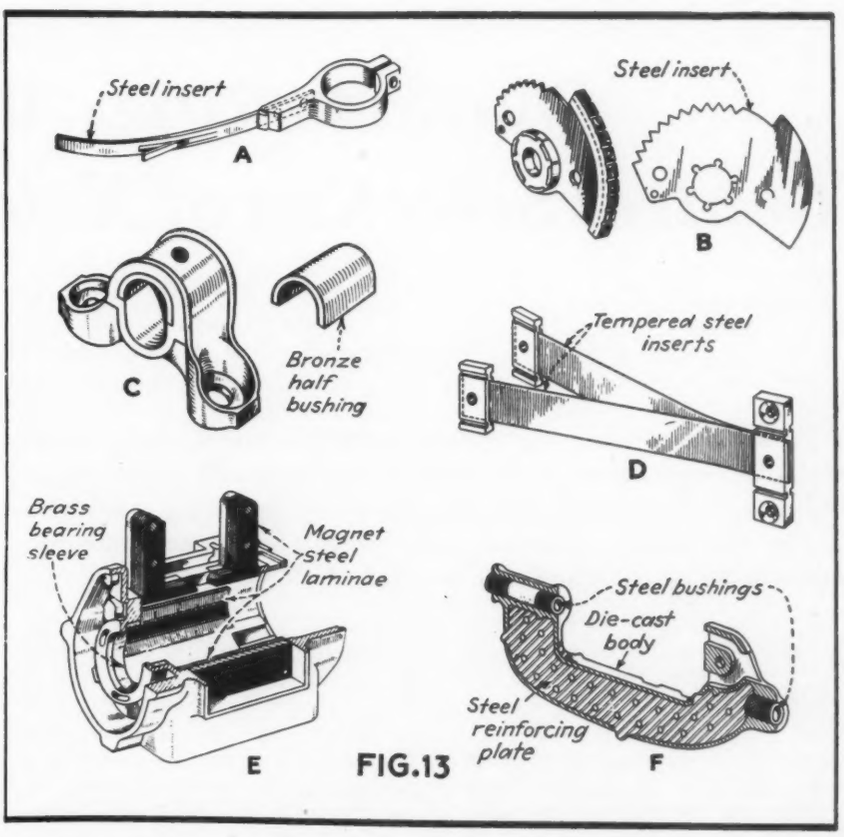
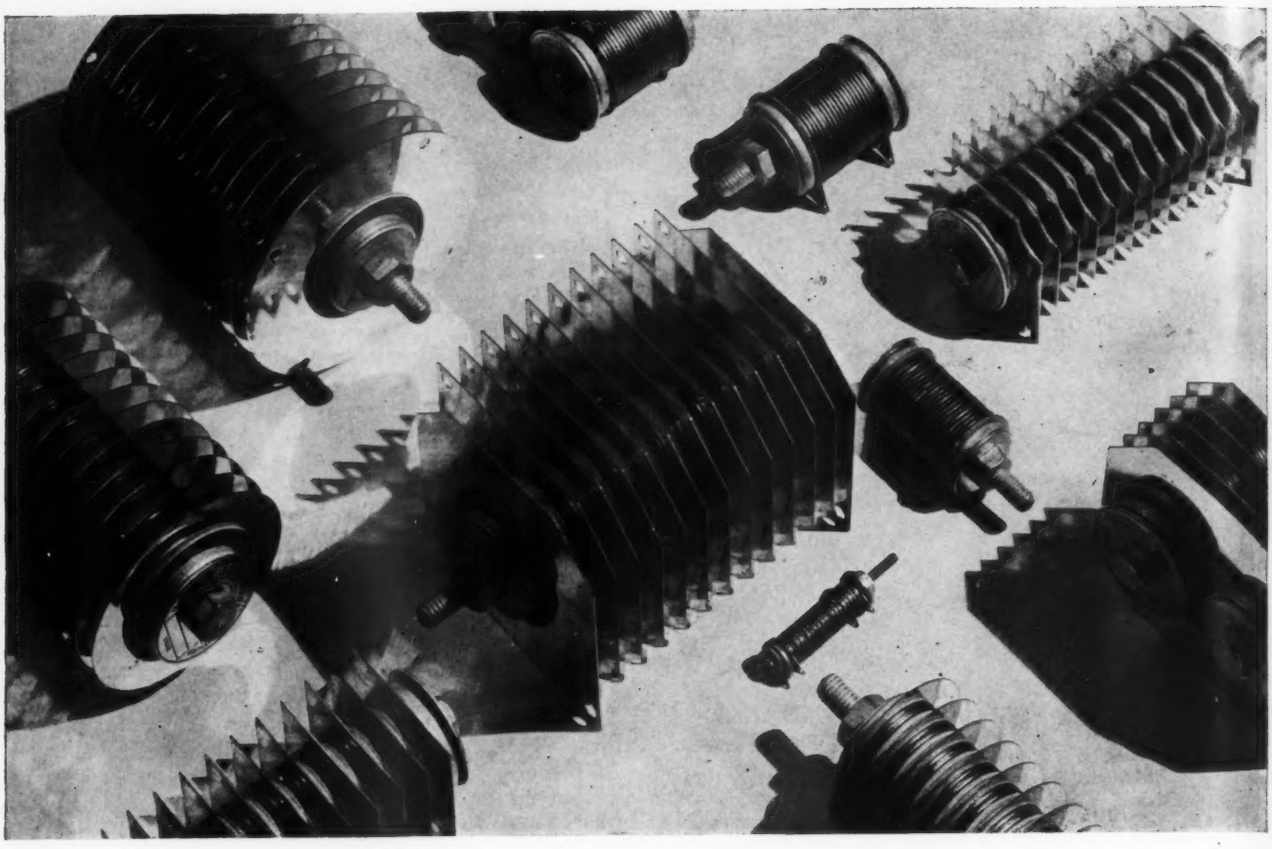


Fig. 13—Group of die-castings in which inserts were cast in place. (A) insert provides strength and stiffness; (B) insert provides wear-resistant teeth; (C) Bronze half bushing for bearing; (D) tempered steel springs form inserts; (E) laminated magnet steel pole pieces inserted; (F) perforated steel reinforcing plate increases bending and shearing strength



Assorted copper-oxide rectifiers

Characteristics Which Control Selection of Metal Rectifiers

I. R. SMITH
Motor Control Engineer,
Westinghouse Electric & Manufacturing Company

Metal rectifiers, when new, have definite characteristics which establish their efficiency and internal resistance. These characteristics are altered by time and temperature or operating conditions, or may even change while the unit is in storage. Hence, efficiency figures must be correlated with the aging factor.

METAL rectifiers are generally used when d.c. is needed and a.c. is available, particularly in the lower wattages, or when the required voltage is low regardless of the amount of current required. These rectifiers are applied just the same as motors or transformers by simply keeping the loading within the unit rating and following the recommended practice as to mounting, ventilation and ambient temperatures.

A rectifier is an asymmetric resistance, that is, it has a resistance to flow of current in one direction which is different from its resistance when the flow of current is reversed. A perfect rectifier would show zero resistance in the forward or useful direction and infinite resistance in the back or blocking direction. No rectifier is perfect. Any metal rectifier will pass some current when voltage is applied in the back direction and will exhibit some resistance to the passage of current in the forward direction. In neither direction do these elements have a fixed resistance. Instead, there is a different value of resistance for every voltage at which the measurement of resistance may be made.

Three types of metal rectifiers are used—copper sulphide, selenium. and copper oxide. For characteristics, applications and design factors of selenium rectifiers, see PRODUCT ENGINEERING, March, 1942, page 135, and May, 1942, page 266. To get the utmost from the rectifiers as with other types of electrical equipment, a knowledge of characteristics is desirable.

Rectifier efficiency in standard practice is expressed as the ratio of d.c.

volts amperes output to a.c. watts input. This is done because in so many applications, such as battery charging for example, it is the average value of current that is important, rather than its R.M.S. (root mean square) or heating value.

A single-phase rectifier is actually a more efficient device than appears on the surface, since it is actually delivering some 20 percent more R.M.S. watts than average watts. In other words, a single phase rectifier which is said to have an efficiency of 60 percent based on d.c. volt ampere measurement at resistance load, actually is operating at an efficiency of about 75 percent based on the difference between the R.M.S. watts input and the R.M.S. output.

On 3-phase, the difference between the average and R.M.S. values of output is only two percent so that the rectifier efficiency is practically the same which ever way it is measured.

Two components form the rectifier losses, the loss due to the forward or load current passing in the low resistance direction through the rectifier, and the loss due to the back or leakage current traveling through the rectifier in the opposite direction.

The forward losses vary with changes in load current while the back losses vary with changes in voltage. Obviously, the overall efficiency will be different at different voltages and currents. For a given load current, by which is meant a fixed forward loss, efficiency may be expected to be highest at the maximum voltage rating of the individual rectifier element.

To illustrate, consider a single element rectifier whose maximum rating is six volts, one ampere. If operated at three volts, one ampere, it is apparent that while the output has been reduced 50 percent, the forward losses have not changed so that the percentage of input used up in the rectifier has increased. The back loss will have decreased, but usually the forward loss predominates.

Statements made as to efficiency should be examined critically. One needs to know under what conditions of loading the measurements were made, and also whether the efficiency is that of a new rectifier or one which has aged in service. For a given application, one rectifier may be more efficient than another, while under a different set of conditions the reverse may be true.

Generally, statements as to rectifier efficiency refer only to the efficiency of the rectifying elements proper. The addition of transformers, reactors, relays and other energy consuming devices will result in an overall apparatus efficiency which is considerably less.

In general, metal rectifiers on resistance loads, single-phase full-wave connection, will exhibit element efficiencies from 35 to 65 percent. On three-phase rectification, the measured efficiency will be higher, due to the practical equality of average to R.M.S. output and will range from 50 to 85 percent. In both cases, copper oxide and selenium rectifiers have the highest efficiencies.

Saturable Reactor Improves Regulation

Regulation, which is the difference between the full load delivered voltage and no-load voltage, expressed as a percentage of full load voltage, is one of the less favorable features of metal rectifiers. This comes from their forward resistance and the voltage drop which it causes. In general, regulation will fall between 15 and 30 percent, depending on the load values and age of the rectifier.

Regulation can be improved by using larger capacity elements for a given load, but this method soon reaches an economic limit. When exceptionally good regulation is needed, an auxiliary device, such as a saturable reactor, may be employed to compensate automatically for the internal voltage drop of the rectifier.

Factors that Influence Characteristics

Great differences of life or dependability will be found among different types of metal rectifiers. So far as can be seen, the copper oxide type of rectifier has no limit to its life and when properly applied and used should last indefinitely. Standard units on life tests have operated as long as 15 years continuously, and are still going.

Characteristics of metal rectifiers change with time, some more than others. Such changes come about usually as the result of operation, or of temperature, or both. In some cases, aging will occur on the shelf, because of temperature; in others, voltage must be applied.

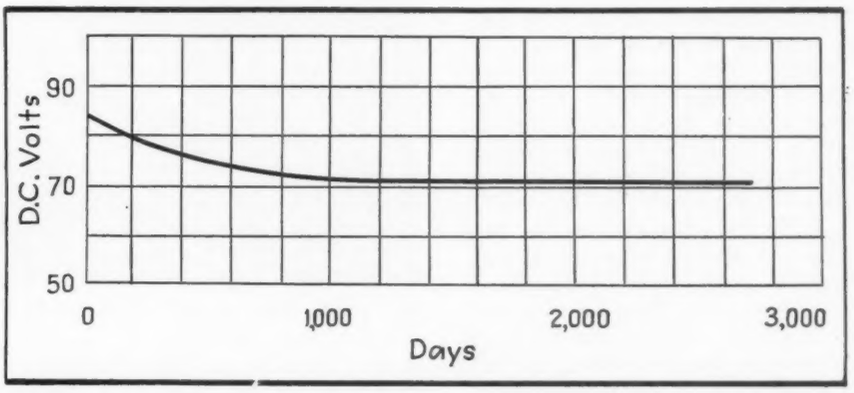
Change of characteristics is not of itself important, if the extent of the changes that may occur is known, and provision made for them. The danger comes in applying a rectifier purely on the basis of its characteristics when new, without allowing any margin for subsequent deviation.

Changes in characteristics, or aging, adversely affect both the forward and back resistance, that is, the forward resistance increases, the back resistance decreases.

Considering the copper oxide rectifier, we find that the change in the forward resistance is purely a function of temperature. At temperatures in the order of 8-10 deg. C., no change occurs. As the temperature is increased, the rate of change also increases. At normal operating temperatures, however, change is very slow.

In the back direction, the resistance of copper oxide units decreases with time and operation. Again, when applying the rectifier, allowance is made for the decrease that will occur during the life of the unit.

In a bridge type rectifier, the forward resistance and amount of forward aging is important. The back resistance is relatively unimportant, so long as it is not reduced to a point where back losses become large enough to affect materially the efficiency or to cause failure of the rectifier. In a valve application, both resistances are important, since it is



Life test curve of the actual performance under continuous operation of a number of full wave Rectox units operating from a constant a.c. voltage into a fixed resistance load

just as necessary to limit the current definitely in one direction as it is to pass it freely in the other.

Where instant operation is important, a rectifier must deliver full-rated output when voltage is applied. There should be no delay to allow building up of rectifying films or for characteristics to settle down.

Ratings Based on Temperature

Like most types of electrical equipment, rectifiers are rated primarily on a temperature basis. That is, values of voltage and current per disc are chosen so that safe operation will result in the expected operating temperature. This presupposes a definite maximum ambient temperature, since the operating temperature of the unit equals the ambient plus the temperature rise. General practice for all types of dry rectifiers is to base their normal ratings on maximum ambient temperatures of 35 deg. C. Operation is permitted at higher ambients for all types, but only after certain derating factors are applied to the normal ratings of the unit. In some cases, the rule is to derate 10 percent in voltage for each 5 deg. C. increase in ambient temperature about 35 deg. C. However, no derating is required in current for copper oxide type rectifiers.

In valve applications, it is sometimes necessary to consider the effect of temperature on the resistance characteristics of the elements, either to be sure the forward resistance does not exceed a desired limit or that the back resistance does not become too low at some point.

Metal rectifiers generally have negative temperature characteristics, that is, the resistance in both directions nearly always increases with decreasing temperature. Hence at low temperatures, the back resistance will be relatively high and so will the voltage drop in the forward direction at any given current. Then as the temperature is increased, the back resistance will decrease, allowing greater leakage current to flow at a given voltage. At the same time, the voltage drop in the forward direction will be reduced. For ordinary ambient temperature ranges, that is from 15 to 35 deg. C., the variation in temperature will be unimportant on most rectifier applications. On outdoor installations, where temperatures may go well below zero, provision must be made so that full output can still be obtained at the lowest temperature.

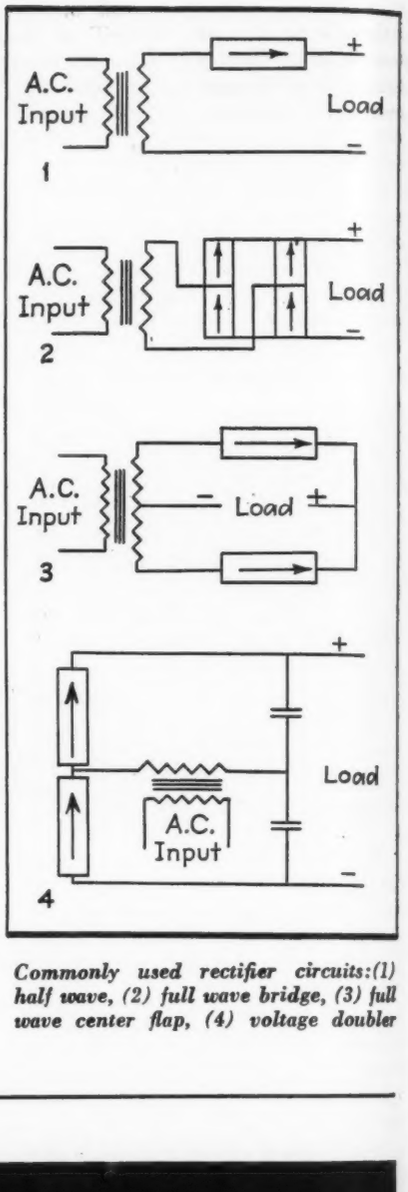
While various rectifier circuits are available to meet different conditions, perhaps four will cover practically all requirements met by small rectifiers. These are half wave; full wave bridge; full wave center tap; and voltage doubler. For a tabulation of the six most common rectifier circuits, see PRODUCT ENGINEERING, page 267, May, 1942.

The half wave connection, which is commonly used with tube rectifiers, is infrequently used with metal rectifiers, since in general there is no economy in its use as compared to a full wave connection, while the output wave form is definitely less desirable for many applications. The half wave rectifier in form, however, is the same as the rectifier valve, which is used to polarize circuits and in this form is commonly found.

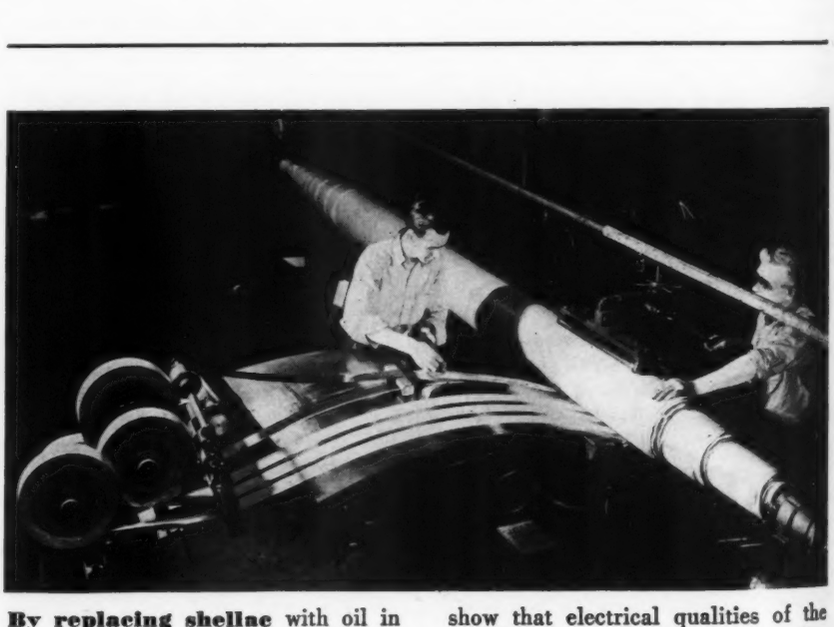
The full wave bridge connection is by far the most common connection used with metal rectifiers, whether single or polyphase. This connection gives the most efficient conversion, together with maximum utility of the transformer. It can also be used without any transformer by connecting direct to the a.c. supply.

The full wave center tap connection is not common with metal rectifiers, as in most cases, no economy is to be gained; the transformer utility is poorer than for the bridge connection. The center tap connection is commonly used with tube rectifiers.

The voltage doubling circuit is limited to cases requiring small currents at quite high voltages, such as for electrostatic precipitators.



Commonly used rectifier circuits:(1) half wave, (2) full wave bridge, (3) full wave center flap, (4) voltage doubler



By replacing shellac with oil in impregnating paper for use of the manufacturer of condenser bushings, the Westinghouse Electric & Manufacturing Company will make an annual saving of 144 lb. of shellac normally imported from India. Tests show that electrical qualities of the new bushing, particularly power factor, are superior to previous types. In this illustration, workmen are shown spiral-winding a large impregnated bushing with layers of paper and copper foil.

INDUSTRY AND SOCIETIES

NEWS • READER LETTERS • MEETINGS

Rubber Problem Easing For Military Needs

TECHNOLOGICALLY, and from the standpoint of military needs alone, this country is practically "over the hump" of its rubber dilemma, according to Dr. L. B. Sebrell, head of the Goodyear Tire & Rubber Company's research department. Research on synthetic rubber has progressed to the point, he said, where it can be converted into almost any needed war product if no more natural rubber was available. Even satisfactory military tires from synthetic rubber are feasible, he said, with their efficiency and suitability decreasing in direct proportion to their sizes.

"Availability of heavy duty tires for civilians from synthetic rubber is a totally separate and unrelated factor," Dr. Sebrell asserted. "Tires of synthetic rubber for civilians and non-war trucking purposes is a problem which can be attacked more vigorously after the more pressing military aspects have been handled. But the day is not far off when we will be 'over the hump' in this respect also."

He pointed out that we are now trying to achieve in two years' time with synthetic rubber what has required nearly 100 years in the development of the compounding and applications of the natural product.

With regard to tensile tests, Dr. Sebrell said that "it is well-known that in pure gum stocks the tensile strength of the butadiene copolymers (buna types) is not as good as that of natural rubber, while that of the butyl rubber does not compare too unfavorably with that of natural rubber." Dr. Sebrell disclosed that the buna types of synthetic rubber are generally the equivalent of natural rubber from a standpoint of flexibility, although the acrolynitrile type of buna rubber more rapidly loses this flexibility at low temperatures.

Emphasizing that the oil-resistant buna types of synthetic rubber are markedly superior to natural rubber in resistance to gasoline, benzol and similar substances, Dr. Sebrell continued, "Natural rubber has the highest resilience of any of the rubbers, although synthetic rubbers show more improvement in resilience as temperatures are increased than does natural rubber." In abrasion resistance, according to Dr. Sebrell, "all synthetic rubbers are more resistant than are similar compounds prepared from natural rubber."

Natural rubber is much more easily plasticized by milling than the synthetics. While the increase in plasticity as a result of between one and ten trips through a rubber mill is very marked for natural rubber, there is a much smaller increase for synthetic rubber in the same number of millings. Natural rubber is less resistant to oxidation than is butyl, while the buna types are superior in the entire group in this respect.

Window frames glazed with Lumapane, a shatter-proof plastic and wire material developed by Celanese Celluloid Corp., are being shipped to arctic and tropical climates for use in prefabricated troop shelters. The panes are easily installed in wood or metal frames, have excellent insulating properties, provide a fair degree of vision, are light in weight, flexible enough to fit unusual contours, unaffected by changes in temperature and humidity and can be cleaned with a water- or kerosene-dampened cloth.

Present Molding Machines Adaptable for Newer Alloys

MACHINES which have been used to mold iron and steel for many years past can be easily adapted to the cast-

More than 2,500 castings for an important piece of Army equipment have been made with a 1,000-lb. capacity portable melting furnace and ladle combination at the General Electric Schenectady works, with a negligible percentage of rejects. The furnace obviates the need for superheating the charge and, by permitting a direct pour from furnace to mold, does away with preheating of transfer ladles and crucibles. The combination is a conversion of a standard oil-fired furnace and ladle. About one-third of the castings made in the portable furnace were of an aluminum alloy of about 5 percent silicon, balance aluminum, corresponding to Navy Specification No. 46A1, Class 2, and among these there were no rejects. The little difficulty encountered was not the fault of the furnace but was due to inexperience in handling another metal when a shift was made to an aluminum-copper-silicon alloy corresponding to Army-Navy-Aeronautical Specification AN-A-4. No "cold shots" were experienced on any of the castings. The furnace is lined with fire brick and needed only two relinings in handling more than 2,500 charges. The furnace and ladle combination, together with its charge, weighs about 3 tons.

ing of the newer magnesium and aluminum alloys with only minor adjustments, according to Russell F. Lincoln, sales manager of the Machine Division of the Osborn Manufacturing Company.

Mr. Lincoln points out that molding machines operate on the same basic principle for both the newer alloys and the older type metals. A minor change in the adjustment of the jolt blow to produce the required hardness of the mold is necessary, but this is practically all that must be done. Special consideration of the type of pattern is necessary and a proper type of molding sand, rammed to the right degree of hardness, is also an important factor.

Marked changes have to be made in gating the mold and in pouring technique. Some foundries, Mr. Lincoln pointed out, have made striking adaptations to the newer techniques. One manufacturer of cylinder heads for airplane engines has so designed the mold gate that a minimum of technique is necessary in pouring. The metal is poured into the sprues and the gates control the flow to the casting.

Discussions and Comments From Readers

PRECISION OBTAINED BY TRIAL AND ERROR

To the Editor:

The method of solving higher equations by trial and error, given by H. A. Bolz in PRODUCT ENGINEERING for April, p. 217, is sufficient for ordinary design work. However, I see no reason for giving the impression that the method is undignified nor that it is merely for rough approximations. I have had many occasions for using trial and error as a precision method.

It should not be forgotten that any use of a table of functions, such as logarithms, trigonometric functions and others, is a trial-and-error type of solution. Such tables are prepared by means of an infinite series to any desired precision. Trial and error is basically a general method of determining terms in a series made rapidly convergent by proper procedure.

Starting with the solution of the equation, now assumed to be

$$t^3 + 0.274500\,t - 0.441000 = 0$$

where Mr. Bolz left off, the following table, showing two steps of approximation, and five calculations give a six-decimal result. A calculating machine is a great help, of course. The method applies to any type of functional relation involving continuous functions, with a few minor exceptions that have an infinite number of solutions near a "singular" point.

In the following table d' is the algebraic difference between functions of t, and d'' is the algebraic difference between successive valves of d'. The change in sign of $F(t)$ indicates the solution occurs between $t=0.64$ and $t=0.66$. The value of t is at some fractional distance n above 0.4. An approximation of two additional places in the solution is obtained by using first differences, d', alone.

Thus:
$n = F(t)/d^1 = 0.003176/0.030842 = 0.1029$

Hence
t (approx.) $= 0.640000 + 0.1029 \times 0.02 = 0.64206$

Greater accuracy is obtained by using both first and second differences. In general

$$F(t)_n = F(t)_o + nd^1 + \tfrac{1}{2}n\,(n-1)\,d''$$

t	Δt	t^3	$0.2745t$	$F(t)$	d'	d''
0.660000		0.287496	0.181170	+0.027666		
	0.02				+0.030842	
0.640000		0.262144	0.175680	−0.003176		+0.001536
	0.02				+0.029306	
0.620000		0.238328	0.170190	−0.032482		
0.642100		0.264733	0.176256	−0.000011		
	0.0001				+0.000151	
0.642000		0.264609	0.176229	−0.000162		
0.642107		0.264741	0.176258	−0.000001		

Thus $0 = -0.032482 + 0.029306\,n + \frac{1}{2}n\,(n-1)\,0.001536$

$0.000768\,n^2 + 0.029306\,n - 0.000768\,n = 0.032482$

$n^2 + 37.159\,n = 42.292$

$(n + 18.5795)^2 = 387.490$

$n = 19.684 - 18.5795 = 1.1045$

Hence t (approx.) $= 0.620000 + 0.02 \times 1.1045 = 0.64209$

In this instance the gain in accuracy is negligible over first differences, but it changes the result in the right direction. The two results are between 0.6420 and 0.6421, which are used for the second approximation. The latter figure proved to be too small, as the two minus signs indicate. However, the value of $0.0001 \times 11/151$ can be added to 0.6421 to give $t = 0.642107$. The check calculation in the last line indicates the size of the error in $F(t)$ when this value of t is used.

In general, other solutions should be sought. In this instance, dividing the function by $(t - 0.642107)$ gives a second degree equation containing two other solutions. It is easily found that both are imaginary, so only one real solution exists.

—Edward A. Richardson
Bethlehem, Pa.

BRUCKNER PRAISES BOLZ TRIAL-AND-ERROR SOLUTIONS

To the Editor:

After reading the article by Prof. Bolz, of Purdue, on trial and error solutions for higher-degree equations, which appeared on page 217 of Product Engineering for April, I am impelled to make comment.

It is indeed unusual for a teacher, more especially from a front-rank university like Purdue, to have the courage to appear in the public print with the bold suggestion that "undignified" non-analytical methods be employed to solve complex equations. However, it is high time that teaching staffs in our engineering colleges began to place more emphasis on mathematical experimentation or trial-and-error as being the most efficient way of getting a job done.

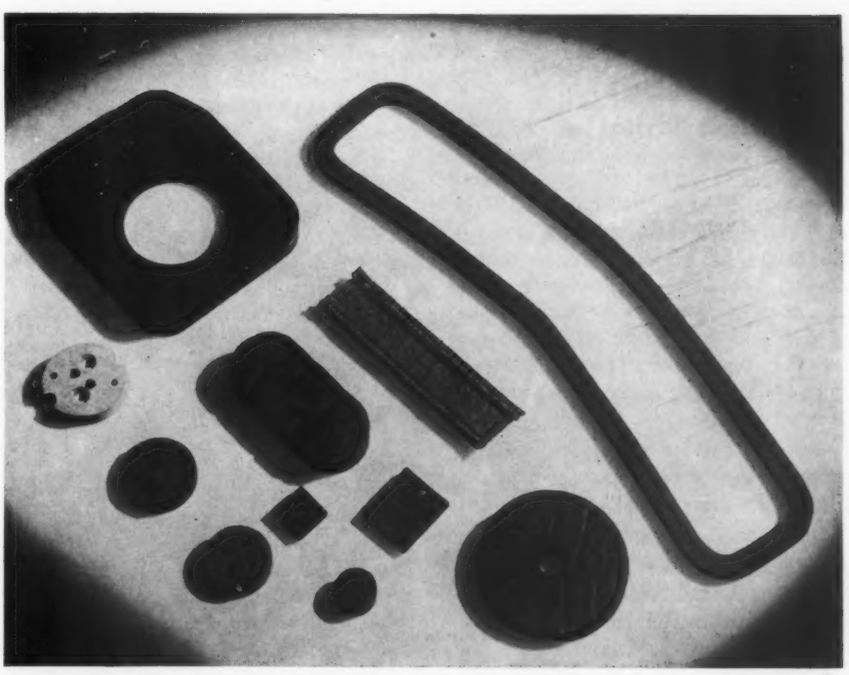
As a practicing machinery designer, this method of solution-by-experimentation has been my own favorite method of attack. Usually in practice, as Prof. Bolz points out, the solution need be accurate only within available shop tolerances, casting variations and the wide margins of strength which must be allowed for unpredicatable variations in apparently identical pieces. And there is no time for the busy practical designer to look up in some library the analytical precision solution, and then take the time to become sufficiently skilled in its use, to apply it safely to the case in hand.

Actually, there are many important problems in the design of hydrokinetic drives, large hydraulic power stations, railroad train-schedule predictions, complex-pattern stress analyses, where the experimental mathematical method is the only method capable of solving the problem. The experimental method is widely used, for example, in torsional vibration problems in engine crankshafts. It appears quite generally in the pioneer mathematical treatments of the Applied Mechanics Division of the A. S. M. E.

With few exceptions, mathematics teachers 20 years ago, and today, largely ignore the experimental method in mathematics, and the stu-

Carbide & Carbon Chemicals Corp.

Quartz crystals for Army "walky-talky" radio sets and other communications equipment are now ground and polished mechanically by holding the crystals in a perforated Vinylite rigid sheet which rotates between fixed steel plates. The lapping disks are easy to handle, do not warp, and give long service.



Cut and molded felt shapes, many chemically treated to resist oil and water, are taking the place of rubber, synthetic rubber, copper and other critical materials in many applications. Some of the shapes developed by Western Felt Works are shown in this illustration.

dent has to acquire intelligent judgment in the use of this method after he graduates. Prof. Bolz and PRODUCT ENGINEERING, far from apologizing, are to be heartily commended for casting the spotlight on this method. —ROBERT E. BRUCKNER

BRITISH READER WANTS INFORMATION ON SPRING MATERIALS

To the Editor:

I am writing to ask if you would kindly assist me re information on the following matter. I am interested in the torsional elastic limit, also the endurance limits of the following materials for springs: Ordinary carbon spring steel, patented wire springs, chrome vanadium, tungsten, brass, spring wire, copper beryllium, Inconel and Monel. I particularly require curves showing how the torsional elastic limit varies for varying wire diameters from 0.01 to 2 in. and should be very grateful for any information given. —M. H. SABIN
Chartered Mechanical Engineer

EDITOR'S NOTE: Readers of PRODUCT ENGINEERING who wish to supply any of the information Mr. Sabine wants can send it to him at 294 City Road, Edgbaston, Birmingham 16, England.

Activities Among Technical Societies

MINERAL WOOL INSULATION COVERED BY NEW STANDARD

Establishment of Commercial Standard CS 105-43, Mineral Wool; Loose, Granulated or Felted Form, in Low-Temperature Installations, has been announced by the Bureau of Standards in cooperation with the Industrial Mineral Wool Institute. The standard covers both cold-storage area and pipe-line mineral-wool insulation. It is considered a major contribution to the war effort in the preservation of perishable food and the maintenance of process-temperature control.

JOSEPH SLEPIAN AWARDED 1942 LAMME MEDAL

Dr. Joseph Slepian, associate director of research, Westinghouse Electric & Manufacturing Company, has been awarded the 1942 Lamme Medal of the American Institute of Electrical Engineers for his contribution to the development of circuit interrupting and current rectifying apparatus. The medal and certificate will be presented at the National Technical Meeting of the Institute in Cleveland, June 21-25.

ARMY, NAVY USE OF GLASS FIBER IS DESCRIBED

How the Army and Navy are using glass fiber materials for electrical insulation was described by Major Hubert B. Keiser, of the Army Services of Supply, at a recent joint New York meeting of the Society of Economic Geologists and the Industrial Mineral Division of the American Institute of Mining and Metallurgical Engineers.

Major Keiser stated that glass insulation, combined with suitable temperature-resistant varnishes and impregnants, is being employed in electrical equipment of all types to provide high stamina and overload capacity in standard-size units; reduction in size and weight, at some increase in temperature rise; high resistance to dampness, acid fumes and abnormal ambient temperatures; and reduction in waste capacity by the use of units at their full rated load, relying on the overload capacity to take care of abnormal operating conditions.

"Some remarkable performance records," Major Keiser said, "have been made by skilled engineering, notably in lightweight compact motors and generators for aircraft, tank, and combat vehicles, and in high reliability control equipment for naval and land artillery."

HEAT-RESISTANT PLASTIC ANNOUNCED TO S. P. I.

Plastic articles that will not soften appreciably or distort at temperatures up to 212 deg. F. can be made of a new formulation of methyl methacrylate molding powder, according to an announcement by Dr. G. M. Kuettel of the E. I. du Pont de Nemours & Company plastics department, at a recent meeting of the Society of the Plastics Industry at Chicago. Airplane flying light lenses, dial and meter faces, medical and dental instruments, and airport and railroad signal light lenses are among the applications of the new molding powder. The formula has approximately the same mechanical, optical, electrical and molding properties as the general-purpose methyl methacrylate molding powders now used for reflectors on military vehicles, Army compasses, Navy control equipment indicators and other items of ordnance. Articles can be made clear, or the powder may be dyed or pigmented to desired colors.

Meetings

Society of Automotive Engineers—Diesel engine and fuels and lubricants meeting, June 2-3, Hotel Carter, Cleveland, Ohio. War Matériel meeting, June 9-10, Hotel Book-Cadillac, Detroit, Mich.

American Society of Heating & Ventilating Engineers — Semi-annual meeting, June 6-7, Pittsburgh, Pa.

American Society of Mechanical Engineers — Semi-annual meeting, June 14-16, Hotel Biltmore, Los Angeles, Calif. Oil and gas power division, July 14-16, Baltimore, Md. Applied mechanics division, July 25-26, Carnegie Institute of Technology, Pittsburgh, Pa.

Society for the Promotion of Engineering Education—Annual meeting, June 18-20, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers — Summer convention, June 21-25, Cleveland, Ohio.

American Society for Testing Materials—46th annual meeting, June 28-July 1, Hotel William Penn, Pittsburgh, Pa.

Do You Know That—

A NEW LUMINOUS PAINT to make objects visible during blackouts owes its luminosity to a non-radioactive substance that is activated by daylight or ordinary electric illumination. After a few minutes exposure to light the paint will glow for hours and, upon re-exposure to light, will become reactivated. (19)

COTTON ROPE toughened with a formulation of a liquid toxic preservative is being tested as a replacement for imported manila and sisal rope for marine use. (20)

GLASS with the same expansion as iron has been developed for use in making electric lamps so that iron alloy wires can be used instead of the nickel-iron-cobalt alloy wire now difficult to obtain because of the shortage in nickel. (21)

Electrical Equipment—Weapons and Tools

From miniature motors to mammoth generators, from tiny detector tubes to great broadcasting stations—everything electrical is essential to our war effort

As this editorial goes to press, newspapers and radio news commentators are telling the dramatic story of the blasting of two mighty Nazi power dams. Floods are sweeping down the Ruhr Valley, Germany's most vital munition production center. Two vast networks of industrial activity lie inert, for the great generators that had fed power to hundreds of plants producing war goods for Hitler, today stand idle. This daring raid will go down in history as one of the most, if not the most devastating of the entire war. It has destroyed two great sources of power, stopping the wheels in hundreds of plants and throwing into darkness thousands of factories and homes.

This epoch-making raid by the R.A.F. brings home to us the vital importance of our own power resources, those colossal generators from which flows the current that turns the wheels of our great industries, illuminates our factories and homes and runs our electric railways and subways. It makes us realize how dependent we are on electricity and how important is the part of those manufacturers who produce the electrical equipment that makes possible its generation and use.

Beginning with Thomas A. Edison, the inventive genius of electrical manufacturing men has devised more and more efficient ways of generating the current, better and better means of transmitting it and of applying it to do thousands of jobs quicker and better.

The products of electrical manufacturers have become so completely an essential component part of every industrial, business and domestic activity that our economy and our war effort could not go on without it.

In days of peace the laboratories of our electrical industry gave us radio, fluorescent lighting, infra-red drying, precision process-control, telemetering, split-second circuit breakers and many other things that border on the miraculous.

Today their facilities and their genius are devoted to an all-out war of wits with Axis scientists and production men.

Electricity plays a significant part in this war . . . from the "walkie-talkie" that brings support to hard-pressed outposts, to the mammoth motors on the battleships. While many electrical developments today are cloaked in secrecy, the nation will enthusiastically applaud these electrical manufacturers when the curtain is lifted.

The far-reaching importance of electrical instruments, apparatus and machines becomes evident when we consider that over 350 different electrical items go into combat vessels and that more than 170 go into a fighter plane. Most of these products are distinctly special in nature and are far removed from their civilian counterparts if, indeed, they have such counterparts.

To the civilian, a light bulb is something so standardized that every need can be filled by any nearby dealer. Our armed forces, by contrast, must have at their disposal more than 400 distinct types of lamps. Some no larger than the head of a match, are so brilliant that they flash signals under a tropical noon sky. Others are built to withstand extremely low temperatures, vibration, shock and many other abuses to which they are subjected.

On planes, for example, numerous fractional-horsepower motors are used but the standard industrial motor is not suitable for this service. New records in low weight-per-horsepower had to be achieved involving extensive changes in design and production.

To prevent the light from instrument panels from impairing the vision of night fighters, ultra-violet radiation which activates fluorescent instrument dials was developed. As a result, the pilot may look out into the darkness after reading his instruments without the least effect on his eyes. How many precious air victories can be credited to this one development alone?

But, in general, the story of this industry's war work is much too blurred by military censorship to afford an adequate picture of its contributions. The factories and shipyards that are turning out war matériel tell a more complete story. Many of these have been built during the past two years. Others have gone through a complete conversion process. In every case, large quantities of electrical materials were involved.

In the broadest sense, there are three major jobs which this industry has had to do, in addition to equipping our modern war machine. It has had to supply materials for the vast expansion of our industrial system, keep every plant fully maintained, and provide the necessary equipment for the vital power and communication fields.

More than $1,900,000,000 was spent for new industrial construction in 1942, and of this about 7% or $140,000,000 was for electrical materials. New machine tools and other production equipment required an additional $350,000,000 worth of electrical products. The conversion program called for another $145,000,000 of electrical apparatus and supplies.

This total of over $600,000,000 in itself would have staggered the electrical industry in a peace-time year. Yet, this record-breaking production was essential and had to be superimposed upon the direct requirements of the Army and Navy.

Industry depends upon electricity. Consider for a moment the effect of modern lighting upon war production. Industry enjoys levels of illumination and color quality that were undreamed of ten years ago. As a result, midnight shifts operate at daytime efficiency. As a matter of fact, many of the more modern plants have no windows at all.

Then there is maintenance. The failure of one single motor or feeder will stop a production line. Electrical manufacturers have had to stand at all times ready to

supply the heavy demand for the maintenance and repair parts that keep our industrial machine operating at top speed. Excess loads, 24-hour schedules and inexperienced production hands combine to shorten the lives of electrical equipment.

Electrical manufacturers have had to supply the greatly expanded needs of our power and communication systems.

New construction of all sorts — war plants, cantonments, war housing — has created a formidable need for additional capacity. Every element in our domestic economy has called for increased communication and power services. All this had to be superimposed upon the vast demands of our armed forces. The magnitude of this task is obvious but it is being successfully accomplished. Every old installation is functioning smoothly and every new one has been ready to function on exact schedule. There has been no failure either in our power or in our communication. Part of the credit for this performance belongs to the hundreds of manufacturers who delivered their products when and where they were needed.

This was not merely a problem of increasing production. These manufacturers had been depending on rubber, copper, aluminum and steel — all highly critical materials. For much of their non-military production they suddenly had either to find substitutes or practice the utmost economy and ingenuity.

Solutions to many problems were quickly found. Lighting manufacturers greatly reduced their use of steel by designing efficient, non-metallic reflectors. Wire and cable manufacturers expanded their use of synthetic insulation in place of rubber and they promoted the use of higher distribution voltages so that every ounce of copper would work more efficiently.

Steel is essential in apparatus that operates magnetically. There is no known substitute. But marked economies in its use have been achieved through the development of new alloys that are of increased magnetic efficiency. As a result, motors and transformers now consume substantially less steel than did units of equal capacity a year or two ago.

Electrical manufacturers have given our industries numerous new production tools. Infra-red heating tunnels, for example, have drastically reduced the time involved in production drying . . . in some cases from hours to minutes. High-frequency induction-heating has been spectacularly successful in the forging, brazing, hardening and casting of ordnance. Modern welding equipment makes possible speedy production with inexperienced labor.

America's production lines are being patrolled by electrical devices which eliminate human error. One million volt X-ray equipment looks through castings and points an unfailing finger at defects. An electronic flaw detector tests nonferrous drawn-metal tubing for imperfections. Other electronic devices are counting and sorting the products of thousands of war plants. Precision controls regulate all sorts of processes, from aluminum production to armor plate annealing.

These are but a few of many examples of the way in which the magic power of electricity has been harnessed to the war effort. Back of every development there is at least one electrical manufacturer — more often many — who have pooled ideas and methods with no thought of royalties or dispute over cost allocation.

No story of the electrical industry would be complete that did not pay tribute to those manufacturers who have dropped their normal lines in order to produce special war products. Many appliance manufacturers fall in this group. When war came, they did not stop to argue that civilian morale and big pay checks would demand a continued supply of their products, instead they quickly shifted to the production of war matériel and today they are deep in the manufacture of machine gun parts, aircraft sub-assemblies, and even gas-mask fabric. They have had to abandon their hard-won markets for the duration; but they are contributing mightily to permanent peace and a more prosperous world to which they will return when the guns are silenced.

This great industry has increased its production threefold in two years — $2,500,000,000 in 1940 to $7,500,000,000 in 1942. It has done this with all the zest of youth, for this is a young and a pioneering industry. Few companies in this industry are fifty years old; the majority are much younger. Top management in general is young, too, and many outstanding technical developments have come from the brains of men just a few years out of college.

The results of all its intensive intelligent work can be found in every factory, on every battlefield and ocean, and even in the flak-spotted air over Berlin. In a sense, the electrical manufacturing industry stands beside every soldier and every sailor as he goes into action. It has a place of honor it richly deserves.

And when this war passes into history, as it surely will, our soldiers and sailors returning to peace-time jobs, will find a life greatly enriched by electrical developments that were undreamed of yesterday.

This is the twelfth of a series of editorials appearing monthly in all McGraw-Hill publications, reaching more than one and one-half million readers, and in daily newspapers in New York, Chicago and Washington, D. C. They are dedicated to the purpose of telling the part that each industry is playing in the war effort and of informing the public on the magnificent war-production accomplishments of America's industries.

James H. McGraw, Jr.

President, McGraw-Hill Publishing Company, Inc.

Books and Bulletins

1943 SAE Handbook

700 pages, 5½x8½ in. Blue clothboard covers. Published by Society of Automotive Engineers, 29 W. 39th St., New York, N. Y. Price $5 to nonmembers.

New and revised data are included on materials such as the non-ferrous emergency specifications and the NE steel compositions, solders, bearing materials, aluminum and magnesium alloys, brass, bronze and copper alloys, zinc alloys and rubber compounds. New data on the AN hardness-tensile strength are also included. In the aeronautical section material specifications, standards, recommended practices and information reports have been revised and expanded.

Powder Metallurgy

WALTER J. BAEZA—*212 pages, 6x9 in. Brown clothboard covers. Published by Reinhold Publishing Corp., 330 W. 42nd St., New York, N. Y. Price $3.50.*

The book gives a short history of powder metallurgy followed by chapters on metal powder production, specifications, their cohesion, and manufacturing problems and machines. This portion of the book gives an interesting overall picture of the industry as it operates today, what its problems and possibilities are. The latter half of the book covers the planning of a college course, giving general instructions and outlining 15 laboratory experiments for students.

Ferrous Production Metallurgy

JOHN L. BRAY—*457 pages, 6x9 in. Red clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price $4.*

This textbook, written as a companion volume to "Non-Ferrous Production Metallurgy," is designed to furnish the basis for a fundamental and comprehensive study of the various processes employed in the production of iron and steel, and also the physical-chemical interactions involved in the metallurgy of these materials.

Descriptions of plant and equipment are accompanied by simple, clear line drawings rather than halftone photographs. Much tabular matter and many graphs are used.

The volume deals with the raw materials from which iron, wrought iron, steel and the ferroalloys are produced; also the plant and equipment associated with production such as the iron blast furnace, cementation and crucible processes, Bessemer process, basic and open-hearth processes, and the electric furnace.

Proceedings

Published by the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa. 1,217 pages, 6x9 in. Black clothboard covers.

This is Volume 42 of the society's proceedings and covers the 45th annual meeting held at Atlantic City, N. J., June 22-26, 1942. Committee reports and technical papers are included.

Substitutes

H. BENNETT — *225 pages. Green clothboard covers. Published by Chemical Publishing Co., 234 King St., Brooklyn, N. Y. Price $4.*

Those who have materials problems will find useful suggestions for substitutes or alternates in this book. As stated in the preface, "the subject matter is in a state of flux and is growing and changing continuously and continually. It should be useful to many as a starting point." The first quarter of the book is devoted to a discussion of numerous chemical and physical properties and characteristics. The rest of the pages compose an alphabetically arranged list of materials and products with possible substitutes or alternatives. No indication is given of the specific properties and characteristics of the materials listed.

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Hardness

D. LANDAU—*105 pages, 6x9 in. Paper covers. Published by The Nitralloy Corp., 230 Park Ave., New York, N. Y.*

The subtitle, "A Critical Examination of Hardness, Dynamic Hardness, and Attempt to Reduce Hardness to Dimensional Analysis," tells what the book covers. The Nitralloy Corporation believes that an understanding of dynamic hardness will yield important advances in engineering. An illustrated history of all efforts to define and measure hardness is interestingly presented with particular attention to a dynamic method of hardness testing, expressing hardness in terms of length, mass and time. The method was developed by the French engineer, P. Roudié. The author believes that, of all those who have worked in this field, Roudié "has given the best direction to which we must shape the course of hardness research." The book also includes a bibliography of 60 references.

National Emergency Steels

EDITED BY ERNEST E. THUM—*72 pages, 8½x11 in.; illustrated. Published by the American Society for Metals, 7301 Euclid Ave., Cleveland, Ohio. Price 50 cents.*

Characteristics and properties of NE steels are covered in considerable detail in this pamphlet prepared to aid the society's many War Products Advisory Committees, which are listed in the back. Of particular interest to designers are the discussions on "Economics of Substitution" and "Predicting A Steel's Properties."

Properties and Applications of Phase-Shifted Rectified Sine Waves

J. TYKOCINSKI TYKOCINER and LOUIS R. BLOOM, *Engineering Experiment Station Bulletin No. 339. 6 x 9 in., 52 pages. Published by the University of Illinois, Urbana, Ill.*

Covers an investigation which had for its purpose the graphical analysis of the properties of wave forms obtained by subtraction or addition of two phase-shifted rectified sine pulses, and to show that new wave forms are also obtainable by subtraction or addition of a full sine wave and a phase-shifted rectified sine pulse. The study deals with properties of biphase rectified sine waves, apparatus for producing phase-shifted rectified sine waves, experimental verification of new wave forms and their properties, mathematical discussion of wave forms, and some particular methods of phase measurement.

Screw Threads and Tap Drill Sizes

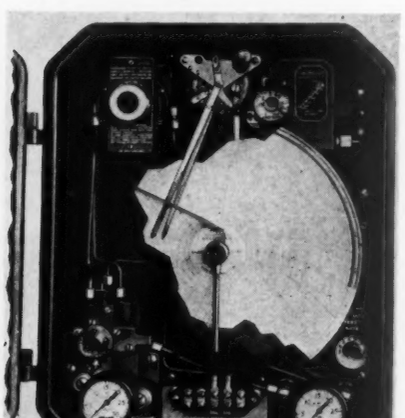
Commercial Standard CS 24.43. Published by National Bureau of Standards. Paper covers, 66 pages. Available from Superintendent of Documents, Washington, D. C. Price 10 cents.

Essential specifications, definitions and dimensional data on screw threads and tap drills, which are recorded more completely in "Screw Thread Standards for Federal Services, 1942" of the National Bureau of Standards Handbook H28, are covered. The predominating sizes of American National Screw Threads in various series and fits, with the corresponding tap-drill sizes, are presented.

NEW MATERIALS AND PARTS

Automatic Manual Control

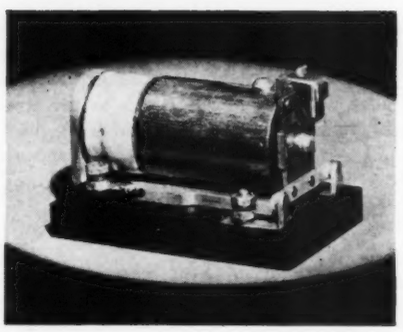
For applications where both automatic and manual control of a continuous process is desired, a unit to provide these features is announced. When the unit is in the "manual" position controlling air pressures are also applied to the idle mechanism which is thus maintained in constant balance. Because of this balance, control can be changed instantly from "manual" to "automatic," without disturbing the process. In addition to "automatic," "manual," and "service"



positions, the new unit has a "test" step. When in this position the control is manual, but the full 20 lb. per sq. in. supply pressure is supplied to the instrument mechanism to make readjustment possible without disturbing the position of the controlled diaphragm valve. Taylor Instrument Companies, Rochester, N. Y.

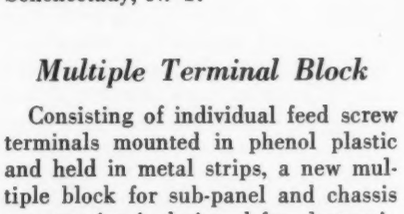
Time-Delay Relay

Specifically designed for aircraft applications where time delay dropout is required, is a new time-delay relay available in two sizes, one providing up to 0.4 sec. time delay, and the other up to 0.3 sec. time delay. The principle by which the relay operates consists of delaying the decay of flux in a magnetic circuit through the use of a single-turn, low-resistance copper jacket around a section of the magnetic structure. Operating temperature ranges from 95 deg. C. to —40 deg. C. The units are suitable for mounting in any position, are corrosion-proof, withstand 95 percent humidity at 75 deg. C. on 48-hr. tests, and operate successfully immediately thereafter. Normally closed double-break silver contacts will carry 20 amp. continuously at altitudes up to 40,000 ft. Coils can be furnished for operation on either 12- or 14-volt circuits. Contacts will remain in position without shattering when subjected to frequencies of from 5 to 55 cycles per sec. at $\frac{1}{32}$-in. amplitude applied in any direction, or when subjected to linear acceleration of 10 G. in any direction. General Electric Co., Schenectady, N. Y.



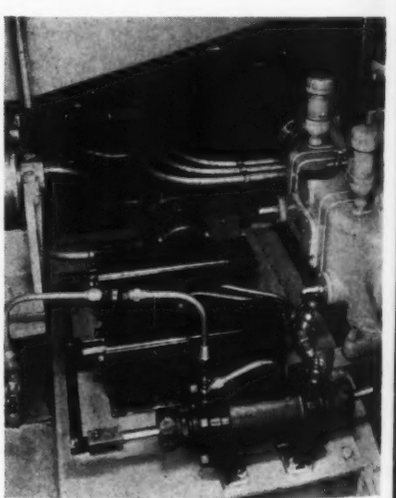
Multiple Terminal Block

Consisting of individual feed screw terminals mounted in phenol plastic and held in metal strips, a new multiple block for sub-panel and chassis construction is designed for electronic and electrical equipment requiring external terminals. Ample clearances and leakage distances for circuits carrying up to 300 volts, 20 amp., are provided. Terminal units are spaced on $\frac{5}{8}$-in. centers and No. 8 screws are used on each side of the terminal unit for connection. Curtis Development & Mfg. Co., 1 N. Crawford Ave., Chicago, Ill.



Electro-Hydraulic Control

Sufficient power to operate the dampers on a butterfly valve or any other equipment requiring remote operation can be transmitted with a control device which combines a Selsyn motor with a hydraulic jet pipe. In operation the Selsyn movement merely operates the sensitive jet pipe and the original impulse is thus transmitted through a hydraulic system. The amount of movement of the receiving

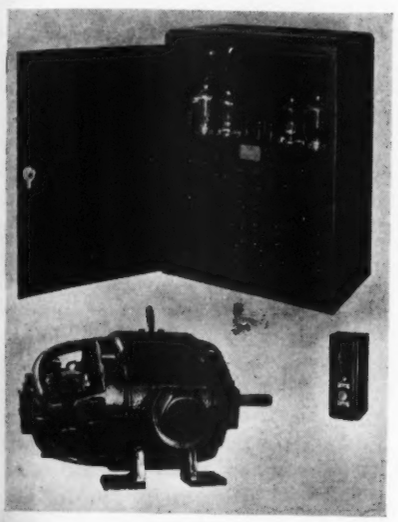


piston is always proportional to the amount of original movement of the Selsyn motor. The cylinder can be used to produce a stroke, force, or rate of turn proportional to the displacement of the transmitter. The factor of power, force or amplification is practically unlimited and accuracies of 0.2 percent are obtained. Illustrated is a typical application in which the speed of a hydraulically-driven worm gear is adjusted remotely by the

electro-hydraulic transmitter. Askania Regulator Co., 1603 S. Michigan Ave., Chicago, Ill.

Adjustable-Speed Drive

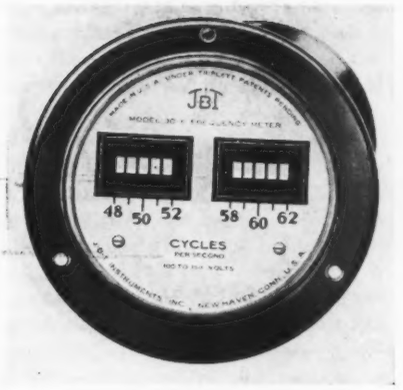
Close speed regulation over a 20-to-1 speed range for d.c. motors operating from an a.c. source is provided for industrial drives by the Mot-O-Trol. This is an adjustable-speed electronic drive which includes stepless speed control, automatic speed regulation over wide load fluctuations, full torque at low speed, smooth acceleration and deceleration and dynamic braking. Four parts make up the new drive. These are power transformers



for separate mounting, Mot-O-Trol cabinet with Thyratron tube and current limiting and speed regulating control, control station with potentiometer to vary the voltage supplied to the armature and field circuit, and with start-and-stop pushbutton, and shunt wound d.c. motor. This drive will be fully described in the Wartime Designs section of June PRODUCT ENGINEERING. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Vibrating-Reed Frequency Meter

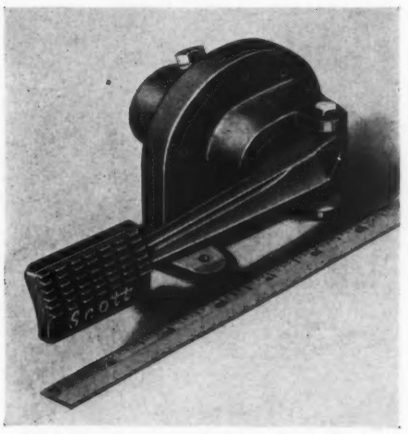
No pointers, pivots, jewels or intricate movements are used in a new line of vibrating-reed frequency meters. Readings are taken from a series of spring steel reeds, each of which is adjusted to respond by resonance to a certain frequency. If the frequency is fractional the reeds on either side of the fraction will vibrate correspondingly. The reeds and mounting bar are insulated from external vibration and there are no screws to adjust. Combinations of reeds as low as



20 cycles or up to 425 cycles are standard, with lower or higher ranges available. There are eight standard models and special reed combinations and case styles may be obtained. Full- or half-cycle increments are standard. Operating range is from 8 volts up, depending on the model. J-B-T Instruments, Inc., 441 Chapel St., New Haven, Conn.

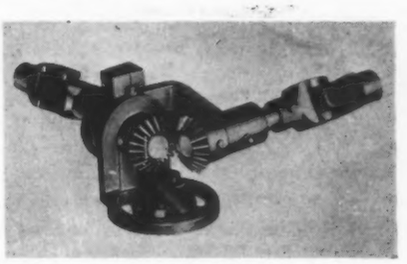
Hydraulic Pressure Generator

Developed originally for actuating wheel brakes in aircraft, the B-711 hydraulic pressure generator has found several industrial applications such as motion transmission and jig actuation. The unit, which is available in several models with different lever and pedal arrangements, permits a sealed system, eliminating the need for a reservoir. Pressures up to 500 lb., with a displacement of 0.8 cu.in., can be obtained. Scott Aviation Corp., Lancaster, N. Y.



Angle Drive Can Be Adjusted

While one shaft of a new universal angle drive remains fixed in either a horizontal or vertical position, the other shaft may be rotated around the axis of the fixed shaft through an angle of 180 deg. and locked in any position within this range. When two of these joints are used, an additional angle of 20 deg. is available on either shaft and a further adjustment can be obtained by revolving the base through 90 deg. by the use of circular slots. Locking is done with a clamp, and the unit may be easily taken



apart by removing two taper pins. It is furnished with or without universal joints. The drive was developed for operation of valves, skylights and ventilators principally on ships and is made in two grades. For shipboard use the frame is cast bronze, the gears are bronze and the shaft is stainless steel. For other uses the frame is cast iron and the shaft and gears are steel. The unit is designed for hand operation and is capable of transmitting approximately ½ hp. at speeds not exceeding 300 r.p.m. Payne Dean & Co., Laconia, N. H.

Air Valve Booster

Intended as an auxiliary device to eliminate the effect of lag in large diaphragm motors and in long air lines between controlling instruments and diaphragm motors is a booster relay air valve. The booster will inflate or deflate a valve motor with a diaphragm of 144 sq. in. from five to seven times faster than by controller alone. It is installed in the air line adjacent to the diaphragm motor and actuates the diaphragm valve by means of an independent air supply of 25 to 150 tons per sq. in. Process

stability is increased by closing the valve action to follow closely the output changes of the controlling instrument. Required set points can be maintained on those applications where time lags and capacities are small. Taylor Instrument Companies, Rochester, N. Y.

Electronic Meter Measures Short Intervals

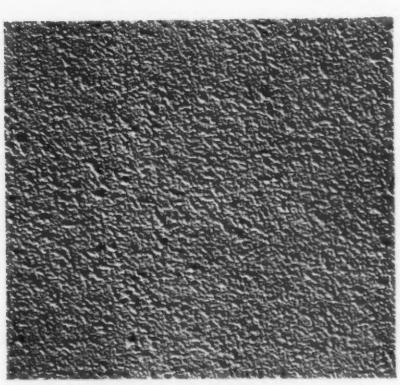
Accurate measurement of extremely short intervals, as low as 100 microseconds, is possible with a new electronic time interval meter, consisting of an electronic panel and a phototube with its pre-amplifier stage. The meter has eight ranges, selected by means of a switch so that any time interval of a length between 0.0001 sec. and 3 seconds can be measured. A standard indicating instrument calibrated in milliseconds gives a direct reading. Operating from 115-volt, 60-cycle lighting circuit, the meter is stabilized so that normal line voltage variations do not affect its accuracy. General Electric Co., Schenectady, N. Y.

Metal Coating Gives Black Finish

Ordinary spray or dipping equipment may be used for the application of Armor-Vit, a coating consisting of silicate combined with an oil-bearing halloysite. A curing treatment combines the ingredients of the coating into a hard, heat-resisting finish that is insoluble in boiling water and highly resistant to many acids and alkalies. The addition of an agglutinating agent increases the ease of application and adherence to the metal base. Armor-Vit is applied in either one or two coats, at 0.0005 to 0.001 in. thickness. The coating is said to withstand the standard 200-hr. salt spray test, extended weatherometer test and many acid and alkali tests. Impact and abrasion resistance also are said to be very high. Heat resistance is demonstrated by the ability of the coating to withstand heat to 1,200 deg. F., followed by quenching in cold water, without failure. It is also said to withstand such acids as acetic, sulphuric, nitric and hydrochloric and such chemicals as cold concentrated caustic soda, ethyl alcohol, toluene, ether, sodium chloride solution, calcium chloride solution, ammonium hydroxide and trisodium phosphate. Chicago Vitreous Enamel Product Co., Cicero, Ill.

Rough Metal Finish

Any metal that has been properly cleaned can be finished with an air-drying nitro-cellulose lacquer known as Pebble-Tex. The lacquer is applied by spray gun only, and the surface may vary from fine, which is illustrated, to rough texture by adjustment of the gun and application technique. For full protection it is recommended that Pebble-Tex be applied over a primer, but the pattern may be obtained with a single application on bare metal. The lacquer is available in a variety of colors. Some uses are on parts for radio equipment, instrument panels and fire control and listening devices. Egyptian Lacquer Mfg. Co., New York, N. Y.

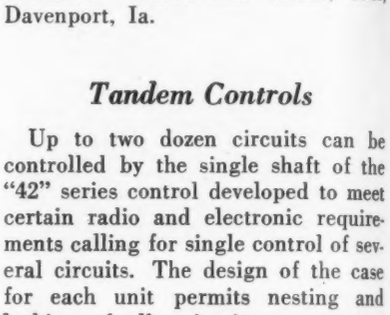


Pressed Wheel Replaces Rubber Units

Suited to many applications where rubber tired wheels were formerly used is a new lightweight, roller-bearing Dual-Disc pressed wheel. It is of 10-in. diameter and consists of two pressed steel disks, steel rims and hubs, all welded into a single unit. Possible applications are on such portable equipment as preheaters for bombers, portable welders, compressors, generators, battery chargers, milking machines, and small concrete vibrators. French and Hecht, Inc., Davenport, Ia.

Tandem Controls

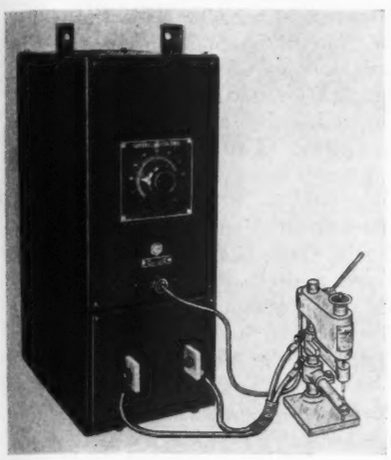
Up to two dozen circuits can be controlled by the single shaft of the "42" series control developed to meet certain radio and electronic requirements calling for single control of several circuits. The design of the case for each unit permits nesting and locking of all units into a compact stack. Metal end disks and tie rods hold the cases together and provide further rigidity. The single shaft passes through and locks with each rotor in the stack. Clarostat Mfg. Co., 285 N. 6th St., Brooklyn, N. Y.



Half-Cycle Electronic Spot-Welding Control

For precise operation of resistance-welding machines an electronic half-cycle synchronous control has been announced. Two types, both mounted in a protecting cabinet are available. The one known as CR7503-A136 includes a welding transformer and is designed for bench mounting, while the unit called CR7503-A133 does not have the transformer and is designed for wall mounting. Both types can be used with either tongs or a suitable bench welder. The control features a new tube, a new circuit

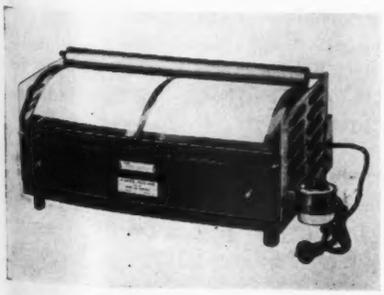
which makes higher-speed welding possible, and a simplified initiating circuit which improves performance and reduces maintenance. Heat control by the phase-shift method is incorporated. Materials which can be welded with the control include tinned copper, steel or alloy wires; studs



from 0.01 to 0.05-in. dia.; flat surfaces with little or no indentation on the opposite surface of the metal and low resistance joints which are unaffected by temperatures considerably in excess of 125 deg. C. Thin sheets (less than 0.01 in.) of stainless or mild steel, nickel, silver, brass and bronze are among the materials which can be spot-welded with negligible oxidation or discoloration. General Electric Co., Schenectady, N. Y.

Table Model Printer Available in Two Sizes

Tracings, drawings, letters and invoices are among the items that can be duplicated on the Spee-Dee printer which is available in two sizes for prints up to 12x18 and 18x24 in. The unit is a portable table model and can be plugged into any standard electric outlet. Printing is done on a curved glass surface. Automatic timer is provided as optional equipment. Either blueprints or black-and-white prints can be made with this unit. Exposure time is as little as 20 sec., and developing time for a black-and-white prints is 10 sec. Peck & Harvey, 4327 Addison St., Chicago, Ill.

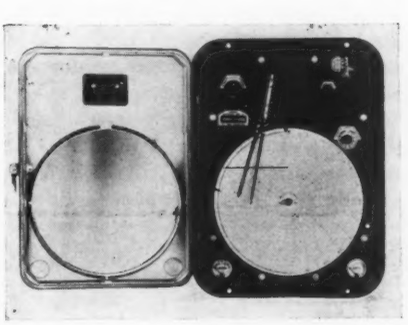


Sheet Metal Features Heat and Corrosion Resistance

Developed for use in products requiring exceptional resistance to heat and corrosion is a specialty sheet metal called Aluminized Steel. It consists of a mild steel face with an aluminum coating and combines the surface advantages of aluminum with the strength of steel. Corrosion resistance is equal to that of an aluminum sheet. When exposed to corrosive attack a tight oxide film, which is self-healing and inert, forms on the surface. The metal is passive in most atmospheres and resists "pin-holding." Heat resistance without discoloration is 1,000 deg. F. and at higher temperatures the metal resists severe oxidation. The aluminum coating will not peal or flake in moderate forming or drawing operations. Paint will hold better than on galvanized sheet. Present aircraft applications include fire walls and air intake filters. The metal is also being considered for cowling. After the war it will be available in a finish that can be highly polished. American Rolling Mill Co., Middletown, Ohio.

Air-Operated Controller

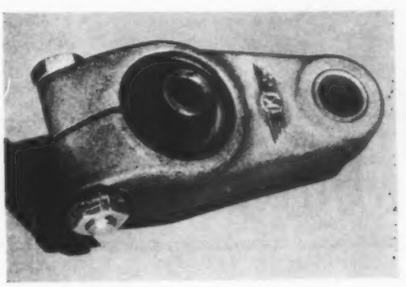
For automatic control of temperature flow up to 3,600 deg. F., liquid level, pressure, draft humidity, pH value, and time program, the Convertible Free-Vane controller is operated by air. This automatic control



instrument incorporates a number of design refinements which simplify the instrument and make it more convenient for servicing. It is also designed so that it can be converted from one type of control system to another. Monoset (on-and-off), Ampliset (throttling), Preset, Reset and Magniset types are offered. Bristol Co., Waterbury, Conn.

Rubber Bushing Is Feature Of Connector Link

Incorporated in an engine-cowl ring connector link for aircraft is a rubber bushing that absorbs engine and flight vibration, together with a simple rocker-arm action or compensating principle that takes up normal engine heat expansion. These features make possible a flexible vibration-absorbing link which reduces split-cowling failures caused by excessive vibration. The new link is molded of aluminum alloy, is heat treated and has an anodized finish. Kinney Engineering Co., Dept. M, 2019 Bay St., Los Angeles, Calif.



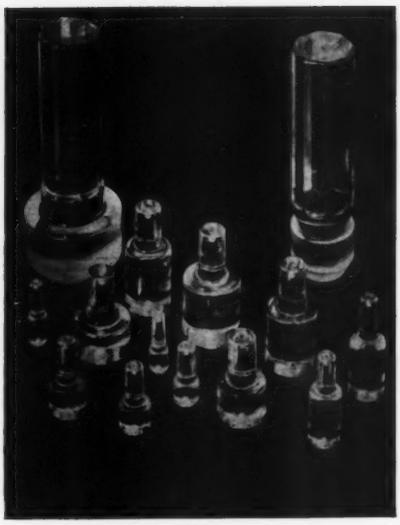
Lightweight Limit Switch

Severe vibration conditions were responsible for the development of a lightweight, dust-tight limit switch especially designed for use where space is limited. The switch has a contact mechanism of the snap-action, double-break type and is available in three different contact arrangements—single circuit, normally open; single circuit, normally closed; and two-circuit, normally open and normally closed. It is also furnished with either die-cast zinc or die-cast aluminum housing and with either counter lug connections or, in the single circuit form, with an AN connector insert built in the AN threaded nipple of

the housing. It is available with a rubber boot mounted over the plunger operating mechanism. Operating range is from 95 deg. C. to −40 deg. C. The switch meets 200-hr. salt water tests and is suitable for use at altitudes up to 40,000 ft. It is a spring-return, plunger-operated type with a $\frac{7}{32}$-in. over-travel. General Electric Co., Schenectady, N. Y.

Glass Gages

Ranging in diameter sizes from $\frac{3}{8}$ to $2\frac{1}{4}$ in. is a new line of glass gages. Additional sizes will be available when molds are completed. Turner Gauge Grinding Co., Ferndale, Mich.



Manufacturers' Publications

Engineering Data—Hyatt Bearings Div., General Motors Corp., Harrison, N. J. Handbook HY-ENG.-1, 96 pages. A "scrap book" of fundamental engineering data such as an engineer or designer might assemble himself from various sources to save time used in going through numerous references.

Finding List—Hobart Bros. Co., Troy, Ohio. Bulletin 120942, 16 pages. This bulletin is the first in a series covering special information and new developments in metals as a contribution to the progress of welding. It covers alloy metals, giving characteristics, trade names, principal constituents and sources.

Coatings—Carbide & Carbon Chemicals Corp., Plastics Div., 30 E. 42nd St., New York, N. Y. Folder, 6 pages. Data on formulations, primer coating, pigments, plasticizers, finish coats, solvents, baking, calendering and cementing of thermosetting vinyl butyral spreader coatings for waterproofing cloth are given.

Gages—General Electric Co., Schenectady, N. Y. Leaflet GEA-3991, 8 pages. Functions of 21 electric gages to aid in production are described. Schematic chart shows electric-gage circuit applications.

Aircraft Accessory—B. F. Goodrich Co., Akron, Ohio. Handbook, 36 pages. Organization of the material in this handbook on de-icers, with particular attention paid to the detail installation diagrams, makes it especially attractive.

Lettering—Rogan Bros. Leaflet, 4 pages. Describes Rogan method of branding or otherwise marking plastic parts.

Connectors—Cannon Electric Development Co., 3209 Humboldt St., Los Angeles, Calif. Bulletin, 82 pages. In addition to general information and tabular matter on Type AN electrical connector plugs, there is included data on junction shells, cable clamps, dust caps, dummy or stowage receptacles and a bonding ring.

Joints—Blood Bros. Machine Co., Allegan, Mich. Catalog, 36 pages, including gatefolds. Complete engineering data on all the types of universal joints made by the company are presented.

Thermoswitches—Fenwal, Inc., 30 Main St., Ashland, Mass. Memo No. 9, 8 pages. Sensitivity, differential, lag and overshoot, heat balance, heat gradients and thermal conductivity of thermoswitches from the standpoint of their selection and application are discussed.

Gear Finishing — Michigan Tool Co., 7171 E. McNichols Road, Detroit, Mich. Manual GF-43, 32 pages. Description of the shaving process of gear finishing, including applications, kinds and sizes of gears and hardness of the materials that can be shaved, how the process can be used to improve quietness and load-carrying capacity and design requirements for obtaining accurate gears.

Tubing—Elmer E. Mills Corp., 812 W. Van Buren St., Chicago, Ill. Circular, 6 pages. Detailed data and physical properties of the plastic tubing and fittings made by this company are given. Charts and tables of working pressures are included.

Fusion—Fusion Engineering, 1836 Euclid Ave., Cleveland, Ohio. Handbook, 8 pages. Recent developments in silver brazing and soldering are disclosed in this initial report on activities in the fusion field.

Tubing — Summerill Tubing Co., Bridgeport, Pa. Bulletin 443, 12 pages. Features a guide chart giving detailed data on the chemical composition and mechanical and physical properties of 25 different metals used by this company in the regular production of round tubing.

Synthetic Rubber—B. F. Goodrich Co., Akron, Ohio. Catalog section, 8 pages. Properties of Ameripol D are discussed. Three pages are devoted to tables, including a rough guide indicating where synthetic rubber is practical.

Brazing—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Booklet B-3201, 12 pages. How to braze with Phos-Copper is discussed. Hints on good brazing are given and diagrams show proper design of butt, scarf, shear and lap joints.

Tool Shanks — Cooper-Bessemer Corp., Mt. Vernon, Ohio. Bulletin 53T-2, 12 pages. Comprehensive description, including specifications, of the company's line of "Victory" tool shanks, made of Meehanite metal, is contained.

Filters — Cuno Engineering Corp., Meriden, Conn. Booklet 1343, 32 pages. Facts about Cuno fluid filter installations in eleven major industrial classifications, with 46 case studies, are included.

Bearings — Bound Brook Oil-Less Bearing Co., Bound Brook, N. J. Bulletin 8 pages. Compo oil-retaining porous bronze bearings and special-shaped parts are covered.

Reinforcement of Nozzles in Pressure Vessels

EDWARD L. MAGUIRE

ONE OF THE MOST CUMBERSOME and time consuming details in the design of pressure vessels is the determination of the need for nozzle reinforcement, as provided by the A.S.M.E. Rules of Construction of Unfired Pressure Vessels. In order to avoid the five mathematical steps into which the procedure may be resolved, the accompanying table was prepared. In applying the tabulated values, which are products of operating pressure, P, times nozzle diameter, D, if the required PD is less than the value shown, no reinforcement is required.

EXAMPLE

Does a 4-in. I.D. × 0.25-in. wall pipe nozzle require additional reinforcement if installed on a 48-in. dia. tank having a shell thickness of $\frac{5}{16}$ in. and subject to 150 lb. per sq. in. internal working pressure?

If all five of the design limits listed below are assumed to apply, $PD = 150 \times 48 = 7{,}200$. The table allows 7,420 for this nozzle size and shell thickness. Therefore, no additional reinforcement is required.

LIMITATIONS IN USING TABLE

1. Shell thickness should be equal to or greater than nozzle wall thickness.
2. Nozzle projects into the shell at least the thickness of nozzle wall.
3. Nozzle weld area should be four times nozzle wall thickness squared.
4. Table is based on shell efficiency of 80 percent. If other efficiency is desired, multiply PD values by $E/0.80$. If 90 percent efficiency is required in the above example, $7{,}200 \times 90/80 = 8{,}100$. Additional reinforcement would then be required.
5. Table is based on a design stress of 15,000 lb. per sq. in. If other design stress is required, multiply PD values by $S_d/15{,}000$. Thus, in the above example, if a design stress of 17,000 lb. per sq. in. is desired, $7{,}200 \times 17{,}000/15{,}000 = 8{,}160$. Additional reinforcement would then be required.

The five steps in the A.S.M.E. method of procedure include determination of the following:

1. Minimum shell thickness—$t = Pr/SE$
   where P = working pressure in tank, lb. per sq. in.
   r = radius of tank, in.
   S = allowable design stress, lb. per sq. in.
   E = joint efficiency
2. Required nozzle cross-section—$A_R = t\ (2d - c)$
   where d = I.D. of pipe nozzle, in.
   c = constant of 2 in.
3. Actual areas of cross-section—$A_A = a + b + c$
   where a (cylindrical shell) $= m\ [2d - (d + 2n)]$
   m = actual shell thickness
   n = pipe nozzle wall thickness
   d = inside diameter of pipe nozzle
   b (nozzle body) $= [(2.5n + 0.5m + n)](2n)$
   c (nozzle body welds) = cross-sectional area of welds $= 4n^2$
4. $A_R \leqq A_A$
5. If A_A exceeds A_R no reinforcement is required. If A_R exceeds A_A reinforcing must be added to outside or inside of nozzle wall in an amount equal to the net difference.

Values of Operating Pressures Times Nozzle Diameters (PD) Above Which Pipe Nozzles Require Reinforcement

Pipe Nozzle Size		Thickness of Tank Shell in Inches						
Pipe Diameter Inches	Pipe Wall Thickness Inches	1/8	3/16	1/4	5/16	3/8	7/16	1/2
2	0.125	4,860	6,320	7,650	9,100	10,500	11,900	13,300
	0.156		7,350	8,750	10,100	11,500	12,900	14,400
	0.187		8,680	10,500	11,450	12,750	13,400	15,500
	0.218			11,600	12,950	14,300	15,650	16,950
2½	0.125	3,750	4,940	6,120	7,350	8,520	9,630	10,850
	0.187		6,540	7,700	8,860	10,000	11,100	12,300
	0.203			8,220	9,380	10,520	12,650	12,800
	0.250			10,000	11,150	12,400	13,300	14,500

(Continued on next page)

Reinforcement of Nozzles in Pressure Vessels (continued)

Pipe Diameter Inches	Pipe Wall Thickness Inches	1/8	3/16	1/4	5/16	3/8	7/16	1/2
3	0.125		4,250	5,320	6,400	7,460	8,540	9,650
	0.187		5,460	6,520	7,560	8,600	9,660	10,720
	0.218			7,300	8,350	9,350	10,400	11,480
	0.250			8,260	9,220	10,300	11,300	12,350
3½	0.187		4,800	5,830	6,780	7,820	8,800	9,800
	0.234			6,800	7,750	8,760	9,800	10,700
	0.250			7,200	8,150	9,160	10,100	11,100
4	0.187		4,400	5,350	6,300	7,280	8,180	9,150
	0.250			6,500	7,420	8,380	9,250	10,250
	0.312				8,840	9,940	10,700	11,620
6	0.250			5,100	5,940	6,840	7,650	8,550
	0.281				6,370	7,250	8,100	8,960
	0.312				6,800	7,650	8,520	9,400
8	0.250			4,520	5,320	6,150	6,980	7,850
	0.312				5,950	6,770	7,650	8,420
	0.375					7,550	8,360	9,200
	0.437						8,950	9,710
10	0.187		2,970	3,780	4,620	5,450	6,170	7,050
	0.250			4,140	5,000	5,800	6,500	7,400
	0.312				5,460	6,250	6,975	7,880
	0.375					6,900	7,600	8,500
	0.437						8,000	8,900
	0.500							10,000
12	0.187		2,840	3,630	4,450	5,280	6,050	6,850
	0.250			3,930	4,750	5,560	6,350	7,150
	0.312				5,150	5,940	6,720	7,540
	0.375					6,450	7,250	8,025
	0.437						7,600	8,400
	0.500							9,280
14	0.187		2,740	3,540	4,340	5,150	5,920	6,720
	0.250			3,780	4,600	5,400	6,200	6,950
	0.312				4,925	5,720	6,500	7,280
	0.375					6,150	6,920	7,700
	0.437						7,225	8,000
	0.500							8,750
16	0.187		2,680	3,460	4,250	5,060	5,850	6,620
	0.250			3,680	4,480	5,280	6,050	6,850
	0.312				4,760	5,550	6,340	7,120
	0.375					5,920	6,700	7,500
	0.437						6,950	7,750
	0.500							8,400
18	9.187		2,620	3,420	4,210	5,000	5,760	6,560
	0.250			3,600	4,400	5,180	5,950	6,750
	0.312				4,660	5,420	6,200	7,000
	0.375					5,750	6,520	7,320
	0.437						6,750	7,550
	0.500							8,140
20	0.187		2,580	3,370	4,150	4,950	5,700	6,400
	0.250			3,525	4,320	5,120	5,875	6,660
	0.312				4,550	5,350	6,100	6,900
	0.375					5,640	6,400	7,160
	0.437						6,600	7,370
	0.500							7,900
24	0.187		2,270	3,300	4,080	4,850	5,640	6,400
	0.250			3,440	4,220	5,000	5,760	6,560
	0.312				4,420	5,180	5,950	6,740
	0.375					5,420	6,180	6,960
	0.437						6,360	7,140
	0.500							7,550